Search for science talent in the Netherlands

Korpershoek, H.

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Hanke Korpershoek

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Promotores:	Prof. dr. M. P. C. van der Werf Prof. dr. R. J. Bosker
Copromotor:	Dr. H. Kuyper
Beoordelingscommissie:	Prof. dr. J. van Damme Prof. dr. H. P. J. M. Dekkers Prof. dr. W. H. A. Hofman

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Hanke Korpershoek

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Chapter 1

General Introduction

During the adolescent years various important decisions are made for the future. Several of these decisions are taken within the context of education. At some point in time students need to make up their mind about their educational career. Which school subjects do they like or dislike? What field of study do they prefer? For these decisions, students need to know where their abilities lie. The decisions students make about their educational career are generally – at least to some extent – in line with their abilities, interests, and future perspectives. Meanwhile, there are also students who for various reasons may not choose to pursue the obvious career path in terms of their abilities. The central focus of the present dissertation is one particular group of students that has not made the obvious study choice. These students possess a considerable amount of "science talent", but have not enrolled in advanced math/science courses in secondary education or if they did, have not opted for a science-oriented study in higher education.

The studies presented in this dissertation were all conducted in the context of low participation rates of Dutch students in science-oriented courses in secondary education (i.e. advanced mathematics, chemistry, and physics) and in STEM courses (science, technology, engineering, and mathematics) in higher education. Despite the reasonable science proficiency levels of the students in Dutch secondary education, schools fail to stimulate many of these students to pursue science-related careers (Organisation for Economic Co-operation and Development, 2009). An increased participation in STEM studies is important for the development of the knowledge society so much aspired nowadays, and is necessary to set off current shortages of employees in the STEM labour market in the Netherlands (Advisory Council for Education, 2007). International comparisons, such as TIMSS-Advanced 2008, show that Dutch students excel in physics and achieve well above average in advanced mathematics. However, in comparison with other countries, only few students take advanced math and physics courses at the highest level (Mullis, Martin, Robitaille, & Foy, 2009). Determining and stimulating talent is one of the objectives of education. From this point of view, it is important to identify students' talents and encourage them to continue to develop their potential in a suitable career. In this context, the STEM career path is often regarded as a pipeline that starts at secondary education and runs via higher education to the job market (Watt & Eccles, 2008). At each transition in the system, potential STEM students flow off before reaching the narrow part of the funnel. This means that only some of the students in secondary education who take advanced mathematics and science courses choose a science-oriented study in higher education. Similarly, not every student who successfully completes a STEM study chooses a science-oriented career after graduation. In the Netherlands, the pipeline starts to narrow in the 9th grade. In this grade, when students are usually 15 years old, they have to choose a set of school subjects arranged in so-called study profiles, in which they will take their Final School Examinations (FSE)[1] (see next section). This is the first opportunity for students to drop (advanced) mathematics, chemistry, and physics. In this way, they prematurely restrict their educational and career options (Meece, Wigfield, & Eccles, 1990). For some of these students advanced math and science courses are simply too difficult, but for others the difficulty level is not a serious issue. The present dissertation focusses on the latter group, namely students who have the ability to pursue a science-oriented career. From this point onwards we will refer to this group as "students with science talent".

The study profile choice at the end of the 9th grade is the first opportunity for students to leave the STEM pipeline. The second occasion is when they continue their formal schooling in higher education. Students who have successfully completed their FSE in advanced mathematics, chemistry, and physics are eligible for numerous studies in almost all higher professional or university disciplines. Although some of these talented students indeed choose a science-oriented study, many of them prefer other fields of study to continue their educational career. As the funnel narrows further, more and more science talent is not utilized. This dissertation represents a synthesis of, in our view, important issues associated with students who, despite their science talent, have not chosen the SCIENCE study profile (including advanced math, chemistry, and physics courses) in secondary education and/or did not opt for a STEM study in higher education. To be able to stimulate the participation in science-oriented courses in secondary and higher education, it is essential to know which students "fit" such a career. It is, for example, important to assess the degree of science talent required for enrolment in the SCIENCE study profile in secondary education. Thereupon, the students who meet this criterion can be identified amongst those who have not opted for this profile. It is, however, also important to know the particular characteristics of SCIENCE students in comparison with science-talented students who have not chosen SCIENCE. For example, they might differ with respect to their personality, their study behaviour, or their motivation and interest. All these factors might explain their decision not to continue the career that suits their talent. The studies presented in this dissertation are meant to increase the general understanding of the influence of these characteristics, thereby contributing to the body of knowledge on this topic.

Before dealing in more detail with the content of the following chapters, we begin with an overview of the current participation rates in the Dutch STEM pipeline in the next paragraph. We will limit ourselves to the upper tracks of secondary education (*senior general secondary education* and *pre-university education*) and the transition to higher education. Our research has not included students in the *preparatory secondary vocational education* tracks, since

[1] A more detailed description of the study profiles can be found in Chapter 2.

these programmes do not prepare pupils for higher education. A short outline of the Dutch educational system is given in Appendix A. Next, this chapter presents a comprehensive description of the content of the thesis as well as a short introduction to the study design. Finally, we will give a brief overview of the chapters.

The STEM pipeline in the Netherlands

Although the number has increased in the recent years (Van Langen & Vierke, 2009), few students meet the criteria to enter STEM studies in the Netherlands. The entry criteria of higher educational studies are contingent upon the study profile in which students have taken their FSE in secondary education[2]. This situation applies to the tracks preparing for higher education, namely senior general secondary education (which prepares for higher professional education) and for pre-university education (which prepares for university). Next, a simplified description of the study profile structure is presented.

At the end of the 9th grade students choose one out of four possible combinations of school subjects, called "study profiles", in which they take their FSE[3]. The study profiles are: science and technology (SCIENCE), science and health (HEALTH), economics and society (ECONOMY), and culture and society (CULTURE). Subjects such as Dutch and English language are common in all profiles. The SCIENCE and HEALTH profiles both include advanced mathematics, chemistry, and physics courses. The content of the HEALTH profile is more elementary and less science-oriented, which is why in this programme less time is spent on these subjects. The HEALTH profile also includes biology. The ECONOMY and CULTURE profiles roughly consist of applied mathematics (both), history (both), economics (ECONOMY), and modern languages (CULTURE). Throughout the thesis we will refer to students who chose the SCIENCE study profile as "science students", and to students who opted for HEALTH, ECONOMY, or CULTURE as "non-science students".

As stated previously, the study profile choice is the first moment in the educational system where sufficiently able students (i.e. students with science talent) leave the STEM pipeline. The study choice after successfully completing the FSE within secondary education is the second moment. In the Netherlands, taking the FSE in the SCIENCE

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[2] The situation described here applies to the student sample used in this research project. These students entered the 7th grade in 1999. In 2007, a number of changes were introduced in the structure of the study profiles and the entry requirements for several higher educational studies.

[3] Some students choose a combination of two study profiles, usually a combination of both science profiles or both society profiles. In 2008, only 3% of the students in senior general secondary education and 7% of the students in pre-university education chose a combination of two study profiles (Statistics Netherlands, 2010).

profile is mandatory for entering STEM studies in higher education. In 2008, about 10% of the students preparing for higher education had taken their FSE in the SCIENCE study profile and were therefore eligible for STEM studies without additional requirements (Statistics Netherlands, 2010). More than one third of these students did not continue their career in a science or technical study. Clearly, the changeover between secondary education and higher education involves a considerable loss of STEM potential. In addition, multiple students took the FSE in the less science-oriented HEALTH profile. In some cases this profile is sufficient for entering STEM studies, but usually only with additional requirements, such as taking an extra advanced physics course or an entry-exam. Seventeen percent of the students preparing for higher professional education and 30% of the students preparing for university took their FSE in the HEALTH profile. However, only one fifth of these students opted for a STEM study in higher education.

In particular few girls chose the SCIENCE profile, even if they had sufficient science talent. They preferred to drop advanced math and science courses as soon as possible, probably due to a lack of interest or a low self-concept of their math ability (e.g. Crombie et al., 2005; Van Langen, 2005). Girls often perceive advanced math and science as (too) difficult and have low expectations of success with regard to these subjects. However, low participation rates of girls in advanced mathematics and science courses in secondary education are undesirable, leading to an unbalanced entry in the science-oriented studies and less suitable career choices (Watt & Eccles, 2008). Girls often favour studies and careers that contribute to fulfilling a useful social role in society, for example, a law or medicine study (Lightbody & Siann, 1997; Lips, 1992; Mullis et al., 2009). These findings suggest that special attention to sex-differences in STEM participation research is justified.

The present dissertation

Many scholars have searched for factors explaining the low participation rates in advanced math and science courses, which has resulted in multiple findings. Our journey continues this search, however, from a somewhat different perspective. Rather than an attempt to explain students' choices in education (e.g. mathematics) by using educational choice models (e.g. Dekkers, 2002; Eccles, 2005; Van Langen, 2005), our main interest is the presumed waste of science talent. We studied students who have the ability to pursue a science-oriented career but who chose not to use this talent. In order to increase students' participation in STEM courses in higher education an optimum development and utilization of talent is needed (Advisory Council for Education, 2004, 2005). Surprisingly, when investigating STEM participation few studies focus on students with sufficient ability, who would be particularly fit to participate in STEM studies and pursue STEM-oriented careers. Moreover, we believe that this "fit" entails more than simply having sufficient ability to pursue a science-oriented career. In order to understand what is "required" for being successful in STEM courses in both secondary and higher education we have attempted to identify the particular characteristics of students who have chosen to pursue a science-oriented educational career. Hence, the general objective of this dissertation has been twofold: (1) to identify particular characteristics of students who enrolled in the SCIENCE profile and/or in a STEM study. More specifically, we were interested in the possible differences between SCIENCE/STEM and non-SCIENCE/non-STEM students with respect to characteristics such as ability, personality traits, study behaviour, and attitudes. Secondly, we attempted (2) to identify students within the non-SCIENCE/non-STEM group who would, on the basis of these characteristics, fit the SCIENCE profile and/or a STEM study. Special attention is given to sex-differences concerning these matters. In short, this thesis covers the following topics in addressing the issues mentioned.

The first part of the thesis (Chapters 2 to 5) is focussed on the secondary education. Two groups of students are important here. First of all, there are students who possess a considerable amount of science talent but who do not utilize it. That is, despite their science talent these students have not chosen the SCIENCE study profile. We studied the size of this group, but also some additional characteristics, such as gender and their actual study profile choices. The main goal was to obtain an adequate estimation of the actual size of the pool of students who wasted their science talent as a result of their study profile choice in secondary education. We believe that this estimate is essential information for educational researchers and policy-makers. Opposite to this group there are the students who possess science talent and actually use it by opting for advanced math and science courses in secondary education (i.e. the SCIENCE study profile). We studied the noteworthy characteristics of these students in order to discover whether they represent a certain type of students. For example, we studied whether science students show any characteristics associated with the "nerd" stereotype. The image of science students is still an unexplored research area, while it might be a confounding factor in student study profile choice. In addition, we looked at the personality characteristics of science students in comparison with those of non-science students to explore the relationship between vocational interests (indicated by study profile choice) and personality characteristics. Students often claim that they do not choose science because they believe it "does not fit" them. We believe that personality characteristics might explain why some talented students choose SCIENCE whereas others do not. Furthermore, we conducted one of the studies in the context of two assumptions that students often have about studying math/science: (1) math/science is too difficult for me, and (2) it is required to work hard to achieve well in these subjects. Hence, we examined what students require to be successful in the FSE-subjects advanced mathematics, chemistry, and physics. For this purpose, we addressed the items *math ability*, *academic achievement motivation*, and *time spent on homework*. This approach would provide us with information about which type(s) of students fit a science-oriented career path.

The second part of this dissertation (Chapters 6 and 7) is a follow-up study of the students addressed in part one, and focusses on higher education. After taking the FSE at the end of secondary education, most students continue their educational career in higher education. In the changeover from secondary to higher education many students with sufficient ability in STEM leave the STEM pipeline. Students either choose a science-oriented study (STEM; e.g. mathematics, physics, or industrial engineering) or another field of study (non-STEM; e.g. law, medicine, or economics). So they either do or do not continue to utilize their science talent. Previous research shows that students – also those with science talent – often have a negative attitude towards STEM studies. Such a negative attitude influences the perceived suitability of a study or career. Moreover, research has also indicated that quite a number of students feel that, although they have completed mathematics and science courses in secondary education, they are not sufficiently capable of starting a science-oriented career. We studied this topic in an innovative way by comparing non-STEM students' attitudes towards STEM studies (referred to as "*stereotypes*") with STEM students' attitudes towards STEM studies (referred to as "*perceptions*"). For example, we compared non-STEM students' stereotypical views about the difficulty level of STEM studies with the difficulty level as perceived by students who have actually chosen STEM. This comparison has revealed whether the common stereotypes reflect reality in any way. Furthermore, we attempted to gain an insight into the question why some eligible students do not choose a STEM study in higher education despite the math/science courses they have taken in secondary education. To this end, we studied in more detail those students eligible for STEM studies who opted for a non-STEM study. We compared their attitudes towards STEM studies with their actual experiences in the non-STEM study of their choice. This part of our research was based on a specific approach related to multi-attribute utility theory, that is, the theory of reasoned action of Ajzen and Fishbein (1980). Several concepts from this theory are used to measure attitude constructs. Finally, we thoroughly investigated non-STEM students whose attitude towards STEM studies was more favourable than that towards their current study. We examined whether these students had been influenced by significant others (e.g. parents, teachers, peers) in their decision to choose a non-STEM study. Students tend to make their study choice within the context of parental expectations and socialization through peers. We suspected that students who had left the STEM pipeline while their attitude towards STEM was favourable might had chosen a study that was recommended by others, for example their parents.

Study design

The data used in this dissertation were collected as part of a large-scale longitudinal cohort study in the Netherlands, the "Cohort Studies in Secondary Education" (VOCL'99; in Dutch: "Voortgezet Onderwijs Cohort Leerlingen"). In this cohort study students are being followed in their educational career from the 7th grade onwards, until they have completed their full-time education. The data collection of VOCL'99 started in the academic year 1999-2000 at 126 secondary education schools, the research sample including 19,391 first year students. The overall sample is considered representative of the schools and students in the Dutch secondary education (Van Berkel, 1999). Information regarding students' background characteristics is available for nearly all students. Moreover, various tests were administered in the first three cohort years to assess the students' intelligence and achievements in, for instance, the Dutch language and mathematics. In addition, extensive questionnaires were used throughout the project, addressing topics such as students' motivation, learning styles, and aspirations. For more information on the VOCL'99 study we refer to Kuyper and Van der Werf (2003, 2005) and Korpershoek, Kuyper, and Van der Werf (2006).

The secondary education segment (Chapters 2 to 5) was investigated by using the VOCL'99 data that was collected between 1999 and 2005. The selection of students who followed one of the two tracks preparing for higher education (senior general secondary education and pre-university education) resulted in an initial sample of 7,252 students. The analyses described in the chapters, however, are based on smaller samples due to missing data on certain necessary variables (as the result of total or item non-response). Consequently, the samples differ slightly across the chapters. For the studies concerning higher education (Chapters 6 and 7) additional data were collected in 2008. A follow-up questionnaire was sent to a subsample of the students from the original VOCL'99 cohort, that is, to those who had completed their secondary education in one of the tracks preparing for higher education. The questionnaire addressed several topics, among which students' study choices and several attitudinal variables. The response group used in Chapter 6 consists of 1,935 students in higher education (higher professional education or university). The response group used in Chapter 7 is a subsample of these 1,935 participants. It includes the students who took their FSE in the SCIENCE or HEALTH profile in secondary education but chose a non-STEM study in higher education (i.e. they did not utilize their science talent). This response group consists of 477 higher education students. Each chapter includes a separate method section with a description of the participants and the variables and instruments that were used in the analyses.

Overview of the chapters

The remaining part of this introduction offers a brief overview of the chapters of this dissertation. The results of our research journey are outlined in six empirical studies. Each study represents views which we believe merit more attention in the educational research on the topics "waste of science talent" and "increasing STEM participation".

The study presented in Chapter 2 shows the degree to which science talent is wasted as a result of the study profile choice in the 9^{th} grade. We used longitudinal data on prior achievements on three math-related tests to establish the (average) math ability of science students. This indicator of math talent was used to detect how many non-science students had math ability scores equal to or higher than the average science student. This comparison revealed how many of these non-science students, according to this criterion, had sufficient math ability to take their FSE in advanced mathematics, chemistry, and physics (i.e. the SCIENCE profile).

In the study presented in Chapter 3, we explore whether the stereotypical image of science students as nerds reflects the truth in any way. The study only included boys. We compared SCIENCE and non-SCIENCE boys with respect to their social contacts, leisure activities, and personality characteristics. The Five-Factor Personality Inventory (FFPI) of Hendriks, Hofstee, and De Raad (1999a) was used to assess the participants' personality characteristics. In addition, we examined the predictive value of the three mentioned variables of students' study profile choice.

Chapter 4 elaborates on the relationship between students' study profile choice and their personality characteristics. This study included both boys and girls and discussed the four study profiles separately. We explored whether there are differences in personality characteristics among students choosing different school subjects (i.e. study profiles). Additionally, we repeated the analyses for students with, according to the analysis in Chapter 2, sufficient math ability to take the FSE in the SCIENCE profile. These analyses identified typical personality characteristics of students with STEM potential. The additional results are included in Appendix B.

Chapter 5 consists of two parts. In the first part, we investigated (sex-)differences in math ability among students pursuing different study profiles in the overall student sample. In the second part, we examined the relative importance of math ability, academic achievement motivation, and homework time in explaining SCIENCE students' examination grades in advanced mathematics, chemistry, and physics. This second part only included SCIENCE students. Based on the literature review presented at the beginning of the chapter, we expected that these three variables would partly predict student achievement. The analyses have indicated what students require to be successful in advanced mathematics, chemistry, and physics at the FSE, for example whether math ability is equally important as a motivation for achievement. In addition, we report on possible mediating and moderating effects of math ability, achievement motivation, and homework time on students' examination grades in advanced mathematics, chemistry, and physics.

Chapters 6 and 7 deal with students' attitudes towards STEM studies in higher education. We distinguished between students who chose a STEM study (i.e. STEM students) and those who opted for another study (i.e. non-STEM students). In Chapter 6 we compare the attitudes of non-STEM students towards STEM studies (*stereotypes)* with those of STEM students (*perceptions*). Next, we discuss the differences in the attitude measures between students who took their FSE at the end of secondary education in the SCIENCE profile and those who took their FSE in other study profiles.

Chapter 7 investigates the attitudes of students eligible for STEM studies who chose a non-STEM study in higher education. This study included both SCIENCE and HEALTH students. As previously explained, HEALTH students are, in some cases, eligible for STEM studies, which is why we included them in this last study. Our aim was to discover whether out of three options the students had made the best suitable choice on the basis of their attitudes. The options were: (1) the study actually chosen, (2) science studies, and (3) technical studies. Furthermore, we investigated the effect of significant others on the students' choice to leave the STEM pipeline.

Finally, Chapter 8 summarizes the main findings of this thesis. Some general conclusions, limitations, and suggestions for future research and educational practice are discussed here.

Chapter 2

Science Talent in the Netherlands

Abstract

In this study, we investigated how many students had a reasonable chance of success at the Final School Examinations (FSE) in advanced mathematics, chemistry, and physics in secondary education but had chosen other sets of school subjects. That is, we estimated the actual size of the not utilized STEM talent pool in secondary education (STEM stands for science, technology, engineering, and math). The longitudinal study included 6,033 students in pre-university education (track A) and senior general secondary education (track B). Students' math ability was used to estimate their STEM talent. The average math ability of students pursuing the science & technology study profile (SCIENCE) served as criterion to detect students with sufficient math ability yet had not chosen SCIENCE. The study demonstrated that, in addition to those already pursuing SCIENCE, at least 20% (track A) to 23% (track B) of the students had sufficient math ability for this set of school subjects in Dutch secondary education. These students were found across all disciplines (study profiles) and were both boys and girls.

Introduction

As a result of international agreements in Europe (European Commission, 2002, 2004), the Dutch government attempts to attract students' interest in so-called STEM studies (science, technology, engineering, and math) (Ministry of Education, Culture and Science, 2004). The European secretaries of state aimed at a 15% increase of students graduating from tertiary STEM courses in the European Union (EU) between 2000 and 2010. However, international comparisons show that the Netherlands still ranks lower than other European countries in terms of the share of students choosing advanced mathematics and science courses in secondary education (Organisation for Economic Co-operation and Development, 2009). In the Netherlands, taking the Final School Examinations (FSE) in the combination of advanced mathematics, chemistry, and physics is mandatory to enter most STEM studies in higher education. An obvious solution to increase students' entry in STEM studies is to stimulate students to attend advanced math and science courses in secondary education. The question is which students have reasonable chance of success in advanced mathematics, chemistry, and physics at the FSE, and therefore can be encouraged to take these courses into consideration. Indentifying students with a reasonable chance of success in these school subjects helps to specify target groups of students suitable for STEM studies in higher education.

The purpose of the present study is twofold. Our first objective is to obtain an adequate estimate of the actual size of the not utilized STEM talent pool in upper secondary education. That is, we investigate how many students could have taken the FSE in advanced mathematics, chemistry, and physics based on their abilities but had chosen other sets of school subjects. Two groups of students are used for the analyses. There are students who had taken the FSE in advanced mathematics, chemistry, and physics (hereafter called SCIENCE students) and there are students who had taken the FSE in other sets of school subjects (hereafter called non-SCIENCE students). In this study, we use the "ability" of SCIENCE students as an indicator of STEM talent. That is, the average *math ability* of SCIENCE students serves as criterion for detecting suitable students among the non-SCIENCE group. For this purpose, test scores on three math-related tests are used to measure students' math ability. Prior performance usually is an important predictor of future achievement, for example examination grades. The longitudinal study of Park, Lubinski, and Benbow (2007) confirms that among highly talented students, math ability is a significant predictor of success in STEM careers (e.g. accomplishments and grades). Moreover, prior achievement has a substantial effect on students' subject choices (Van Langen, 2005), which is why we chose these measures. Hence, the analyses result in an estimated percentage of students who, based on their math ability, had a reasonable chance of success at the FSE in SCIENCE.

Our second objective is to find out which sets of school subjects these students had chosen (the so-called "study profiles"[1]) instead of SCIENCE, and whether it concerned mainly girls, boys, or both girls and boys. Information regarding the study profiles these students had chosen increases our understanding of the interests and preferences of STEM talent among non-SCIENCE students. We search for sex differences among the STEM talent group, because girls are under-represented in advanced mathematics and science courses in secondary education as well as in STEM courses in higher education (Organisation for Economic Co-operation and Development, 2009; see also Mullis, Martin, & Foy, 2008; Organisation for Economic Co-operation and Development, 2007). Moreover, sex appears to be the key factor in accounting for differences in the number of science subjects chosen at the final examination level of (upper) secondary education after controlling for prior achievement (Dekkers, Bosker, & Driessen, 2000; Kuyper, Van der Werf, & Lubbers, 2000; Roger & Duffield, 2000; Uerz, Dekkers, & Beguin, 2004; Van Langen, 2005).

Van Langen and Vierke (2006, 2008) addressed similar issues in their studies, using course marks for the assessment of science talent. Based on students' average course mark on math, chemistry, and physics in the 9th grade, they evaluated how many students could have chosen the SCIENCE profile. For track A students they used an average course mark of at least a 7.5 (on a scale from 1 to 10) as criterion (Van Langen & Vierke, 2006). They showed that 26% of the girls and 37% of the boys could have pursued SCIENCE based on this criterion, but that a large group of students, especially girls, did not choose SCIENCE even though they had high grades. Only 19% of the girls with high grades chose SCIENCE versus 60% of the boys with high grades. Simple number work tells us that 21% of the overall group of girls in track A could have chosen SCIENCE (.81 * 26% = 21%) but chose otherwise and 15% of the overall group of boys in that track (.40 * 37% = 15%). For track B students the criterion was an an average course mark of at least a 7.0 (Van Langen & Vierke, 2008). Respectively 15% of the girls and 25% of the boys could have pursued SCIENCE based on this criterion but only 5% of these girls and 52% of these boys chose SCIENCE. Of the overall group of track B girls, 14% could have chosen SCIENCE (.95 * 15 = 14%), and 12% of the overall group of track B boys could have chosen SCIENCE (.48 * 25 = 12%). In the present study, we assess students' math ability with independent measures instead of course marks. Although students make use of their course marks when choosing a study profile, these marks can be subjective assessments from teachers, and course marks can measure performance as well as effort.

[1] See method section for more information regarding the study profiles.

Method

Participants

The data used in the study were collected as part of a large-scale longitudinal study in the Netherlands, the "Cohort Studies in Secondary Education" (VOCL'99). In this project students are being followed in their educational career from the 7th grade onwards until they have completed their full-time education. The complete sample is considered representative of schools and students in Dutch secondary education (Van Berkel, 1999). Information concerning students' background characteristics (sex, socioeconomic status, and ethnicity) is available for nearly all students of the overall VOCL'99 sample. Moreover, various tests were administered in the first three cohort years to assess students' intelligence and achievement in for instance Dutch language and mathematics. For more information on the VOCL'99 study we refer to Korpershoek, Kuyper, and Van der Werf (2006) and Kuyper and Van der Werf (2003, 2005).

For the present study we first selected students who were in one of the preparatory tracks for higher education, which are pre-university education (hereafter called track A) and senior general secondary education (hereafter called track B). The participants started their educational career in 1999 and had taken their Final School Examinations in the spring of 2004, 2005, and/or 2006. These students usually were between 16 and 18 years old. Eliminating 260 students of which their chosen study profile[2] was unknown, the first selection resulted in 7,252 students. These were respectively 2,999 track A students (2,580 regular students, 352 students who repeated one year, and 67 students who failed the previous occasion for their FSE) and 4,253 track B students (2,526 regular students, 1,602 students who repeated one year, and 125 students who failed the previous occasion for their FSE). From this group we selected students for whom a measure of math ability could be constructed based on three math-related tests. This was the case for 6,033 students (83%). For the other students a measure of math ability could not be constructed due to non-participation of schools and/or drop out of individual students during the data collection. That is, some schools had prematurely ended their participation in the cohort study or had not administered all requested tests (e.g. mathematics tests). To a lesser extent, students who repeated a grade, declined to participate, or had dropped out of school did not participate in the data collection.

Table 1 gives an overview of the participants, how many boys and girls were included, and which study profiles they had chosen.

[2] The study profiles are explained in the *Variables and Instruments* section.

Table 1 *Overview of the participants*

	Track A				Track B			
	N	% total	% boys	% girls	*N*	% total	% boys	% girls
SCIENCE	370	14.7	28.8	3.1	350	9.9	20.6	1.0
HEALTH	734	29.3	23.8	33.8	504	14.3	13.8	14.7
ECONOMY	844	33.6	39.8	28.5	1,379	39.1	51.7	28.6
CULTURE	561	22.4	7.6	34.6	1,291	36.6	13.9	55.6
Total	2,509	100.0	100.0	100.0	3,524	100.0	100.0	100.0

In comparison to the firstly selected VOCL'99 sample (7,252 students) our sample is representative of students' study profile choices (differences ≤ 1%).

Variables and instruments

Study profile. At the end of the 9th grade students in track A and B choose one out of four possible combinations of school subjects called "study profiles" in which they take their FSE. The students' choices were provided by Statistics Netherlands (CBS). Next to science & technology (SCIENCE), students can choose science & health (HEALTH), economics & society (ECONOMY), or culture & society (CULTURE), or a combination of two profiles. Besides subjects that are common in all profiles (e.g. Dutch and English language), SCIENCE and HEALTH students take their FSE in advanced mathematics, chemistry, and physics; less time is spent on these subjects in the HEALTH profile, as their content is more elementary and less science-oriented in this profile. The SCIENCE profile is mandatory for entering STEM studies in higher education[3]. The HEALTH profile also includes biology. The ECONOMY and CULTURE profiles roughly consist of applied mathematics (both), history (both), economics (ECONOMY), and modern languages (CULTURE). Formally, the study profile choice is unrestricted and is based on students' interests and ambitions. However, the student's decision usually takes place in interaction with his/her parents, teachers, and school counsellors and, can therefore be restricted to some extent. For the present study, students were divided into SCIENCE students and non-SCIENCE students (HEALTH, ECONOMY, and CULTURE). Students who had chosen two profiles (mostly a combination of the two science profiles or the two society profiles) were assigned to the most science-oriented profile. This was the case for ≤ 1% of the students.

Mathematical ability. The construction of math ability was based on three math-related tests, which in essence represent a combination of nature (ability) and nurture (achievement). The combination of these three tests yields a highly reliable measure for math ability, providing the opportunity to compare the math ability of students with a large amount of certainty about their actual mathematics potential. The first test was an

[3] HEALTH students are eligible to some STEM studies with additional requirements.

arithmetic test administered in the 7th grade, developed by the Dutch National Institute for Educational Testing (Cito). The reliability (α) of the test is .83. Second, an intelligence test was used (the Groninger Intelligentietest voor Voortgezet Onderwijs [the Groningen Intelligence Test for Secondary Education], Van Dijk & Tellegen, 1994). The test was administered in the 8th grade. It was assessed as reliable and valid (Evers, Van Vliet-Mulder & Groot, 2000). The test consisted of a verbal and a symbolic intelligence part of which the scores on symbolic intelligence were used (α for the symbolic intelligence part was .93). Third, a mathematics test for the 9th grade was used (also developed by Cito), of which the reliability (α) was .78. We calculated a combined math ability score for students who had completed at least two of these three tests (6,033 students). For this purpose, we transformed the test scores into standardized z-scores and performed a factor analysis on these scores. This analysis resulted in one factor with an Eigenvalue of 1.963 (65% common variance) and communalities of .64 (arithmetic test), .71 (symbolic intelligence test), and .62 (mathematics test). Thus to a large extent the three tests measured one common aspect of math ability. In the combined score, possible differences in weight (of the tests) were taken into account by using regression coefficients as weights. This was done as follows. First, a regression analysis was computed on the complete cases. Second, three separate regression analyses were computed, each with one of the three test scores missing. Third, the resulting regression coefficients were used in the regression equation to "predict" math ability and the test scores were standardized again. The range of this (standardised) score of math ability ran from -3.55 up to 4.44. For track A, the average score on math ability was 0.51 (standard deviation 0.91), and for track B -0.36 (standard deviation 0.90). The resulting scores correlated .99 with the unweighted averages of the three test scores. Following recommendations of Kamata, Turhan, and Darandari (2003), stratified-alpha (as proposed by Cronbach, Schönemann, & McKie, 1965) was used to estimate the reliability of our math ability measure; this is intended for situations where several subtests can be grouped into components of one test on the basis of content. In our sample, the estimated reliability was .92.

Procedure

Within each track (A and B), students were split into (a) students who had a math ability score equal to or higher than the average math ability score of SCIENCE students (hereafter called "high math ability") and (b) students who had a math ability score lower than the average math ability score of SCIENCE students (hereafter called "low math ability"). The average math ability of SCIENCE students then serves as criterion for detecting students among the non-SCIENCE group with sufficient math ability for taking the FSE in these subjects. This approach gives the minimum percentage of students who could have pursued SCIENCE, based on their math ability. Table 2 shows the average score on math ability in both tracks for all 6,033 students included in the study, per profile (SCIENCE, HEALTH, ECONOMY, and CULTURE), separately for boys and girls.

Table 2 *Average score on mathematical ability (standard deviations in parentheses), split by track and sex*

	Track A			Track B			Total
	Boys	Girls	Total	Boys	Girls	Total	
SCIENCE	1.07	1.23	1.09	0.22	0.52	0.24	0.68
	(0.87)	(0.79)	(0.87)	(0.81)	(1.02)	(0.82)	(0.94)
HEALTH	0.72	0.63	0.67	-0.13	-0.14	-0.13	0.34
	(0.84)	(0.86)	(0.85)	(0.78)	(0.93)	(0.87)	(0.94)
ECONOMY	0.52	0.29	0.42	-0.25	-0.40	-0.31	-0.04
	(0.85)	(0.79)	(0.83)	(0.85)	(0.88)	(0.87)	(0.92)
CULTURE	0.26	0.02	0.05	-0.55	-0.69	-0.66	-0.45
	(0.92)	(0.84)	(0.85)	(0.82)	(0.86)	(0.85)	(0.91)
Total	0.71	0.34	0.51	-0.18	-0.51	-0.36	0.00
	(0.90)	(0.88)	(0.91)	(0.86)	(0.90)	(0.90)	(1.00)

Track A SCIENCE students have an average math ability score of 1.09. This average score serves as criterion for detecting STEM talent among non-SCIENCE students in that track. For track B, the average math ability score of SCIENCE students is 0.24.

Results

In total, 628 students of the 2,509 students in track A (25%) had a math ability score equal to or higher than the average math ability score of SCIENCE students in that track. This high ability group consisted of 197 students who pursued SCIENCE (53% of the SCIENCE group) and 431 students who had chosen other profiles (20% of the non-SCIENCE group). These were 202 boys (47%) and 229 girls (53%). So according to our criterion at least 20% of the non-SCIENCE students in track A had sufficient math ability for the SCIENCE profile. Similar results were found for track B students: 900 students of the 3,524 students had high math ability (26%). This group consisted of 181 students who had chosen SCIENCE (52% of the SCIENCE group) and 719 students who could have chosen SCIENCE based on their math ability but did not do so (23% of the non-SCIENCE group). Again, these were both boys (N = 351; 49%) and girls (N = 368; 51%). Hence, comparable to the percentage we found for track A, at least 23% of the non-SCIENCE students in track B had sufficient math ability for taking the FSE in advanced math, chemistry, and physics.

Table 3 shows the percentages of students per group (high versus low math ability), split up by chosen study profile. For example 25% of the high math ability students in track A pursued ECONOMY (and could have chosen SCIENCE based on their math ability).

The table shows that STEM talent (high math ability students) among non-SCIENCE students in track A was found mostly in HEALTH (35%) and ECONOMY (25%) and to a lesser extent in CULTURE (9%). In track B, STEM talent was found predominantly in the ECONOMY profile (41%) but also in the HEALTH (19%) and CULTURE profiles (19%). Moreover, the results indicate that the study profile choices differed between high and low math ability groups. Students with high math ability chose the SCIENCE and HEALTH profiles more often and the ECONOMY (only in track A) and CULTURE profiles less often than students with low math ability.

Table 3 *Percentages of students per group (high versus low math ability), split by track*

	Track A		Track B	
	% high math ability	% low math ability	% high math ability	% low math ability
SCIENCE	31.4	9.2	20.1	6.4
HEALTH	34.7	27.4	19.4	12.5
ECONOMY	24.7	36.6	41.0	38.5
CULTURE	9.2	26.7	19.4	42.5
N	628	1,881	900	2,624

The differences between the high and low ability groups were significant, χ^2 (3, N = 2,509) = 249.99, $p < .001$ (track A), χ^2 (3, N = 3,524) = 247.02, $p < .001$ (track B). All in all, the results show that according to our criterion at least 20% of the non-SCIENCE students in track A (track B: 23%) had sufficient math ability for the SCIENCE profile. Moreover, students with sufficient math ability were found in all profiles.

Furthermore, we investigated sex differences among the student groups in more detail. In short, we found that in track A at least 25% of the non-SCIENCE boys and 17% of the non-SCIENCE girls had sufficient math ability for SCIENCE. For track B, these percentages were respectively 28% (non-SCIENCE boys) and 19% (non-SCIENCE girls). These students were found in all profiles, albeit that there were some differences between the tracks. More specifically, the results are as follows. Of the high math ability boys in track A, 173 had chosen SCIENCE (53% of the SCIENCE boys) and 202 had chosen other profiles (25% of the non-SCIENCE boys). Of the high math ability girls in that track only 24 had chosen SCIENCE (57% of the SCIENCE girls); the 229 others had chosen other profiles (17% of the non-SCIENCE girls). The results for track B are similar. In track B, the high math ability boys group can be divided into 169 boys (51% of the SCIENCE boys) who had sufficient math ability for SCIENCE, and 351 boys (28% of the non-SCIENCE boys) who had chosen other profiles. Of the high math ability girls in track B, only 12 had chosen SCIENCE (60% of the SCIENCE girls), whereas 368 girls had chosen a non-SCIENCE profile (19% of the non-SCIENCE girls). Subsequently, Table 4 shows the percentages of students per group (high versus low math ability), split up by chosen study profile and sex.

Table 4 *Percentages of students per group (high versus low math ability), split by track, study profile, and sex*

	Track A		Track B	
	% high math ability	% low math ability	% high math ability	% low math ability
Boys:				
SCIENCE	46.1	20.3	32.5	14.9
HEALTH	23.7	23.9	14.4	13.5
ECONOMY	27.2	46.0	46.3	54.3
CULTURE	2.9	9.8	6.7	17.3
Total	33.0	67.0	32.4	67.6
Girls:				
SCIENCE	9.5	1.6	3.2	0.5
HEALTH	51.0	29.9	26.3	11.9
ECONOMY	20.9	30.2	33.7	27.3
CULTURE	18.6	38.3	36.8	60.3
Total	18.5	81.5	19.8	80.2

The results of Table 4 indicate that the study profile choices differed between high and low math ability groups for both sexes. Obviously, boys with high math ability chose the SCIENCE profile more often and the ECONOMY and CULTURE profiles less often than boys with low math ability (in both tracks). The differences between the high and low ability groups were significant, χ^2 (3, N = 1,138) = 96.31, p < .001 (track A boys), χ^2 (3, N = 1,604) = 86.23, p < .001 (track B boys). The results for girls differed between the tracks. In track A, girls with high math ability pursued the SCIENCE and HEALTH profiles more often and the ECONOMY and CULTURE profiles less often than girls with low math ability, χ^2 (3, N = 1,371) = 98.73, p < .001 (track A girls). In track B, girls with high math ability pursued SCIENCE and HEALTH more often and CULTURE less often than girls with low math ability, χ^2 (3, N = 1,920) = 97.78, p < .001 (track B girls).

Conclusions and discussion

In this chapter, we investigated how many students had a reasonable chance of success at the FSE in advanced mathematics, chemistry, and physics but had chosen other sets of school subjects. The objective was to obtain an adequate estimate of the actual size of the not utilized STEM talent pool in upper secondary education. Moreover, we investigated which sets of school subjects (i.e. study profiles) these students had chosen instead of SCIENCE, and whether it concerned mainly girls, boys, or both girls and boys. The average math ability of students who took their FSE in advanced mathematics, chemistry, and physics served as criterion for detecting students with sufficient math ability for taking the FSE in these subjects. The measure of math ability was based on students' scores on three math-related tests. The results clearly indicate that more students could have chosen the SCIENCE profile than currently is the case. For track A students, our results revealed that at least 20% of the non-SCIENCE students had sufficient math ability for the SCIENCE profile. For track B students, the percentage was 23%. Moreover, we found that students with sufficient math ability appeared in all profiles and that it concerned both boys and girls. STEM talent among non-SCIENCE students was found mostly in the HEALTH (track A) and ECONOMY (both tracks) profiles. We found that approximately 1/4 of the non-SCIENCE boys and almost 1/5 of the non-SCIENCE girls in both tracks could have pursued SCIENCE but had chosen other profiles.

Our results are basically consistent with the results of Van Langen and Vierke (2006, 2008) presented in the introduction, in particular our reported percentages for girls (i.e. almost 1/5 of the non-SCIENCE girls had sufficient math ability for SCIENCE). However, we found higher percentages for boys (i.e. 1/4 of the non-SCIENCE boys instead of 1/7). Differences in measured constructs presumably affected the outcomes, since we for instance did not take students' ability on chemistry and physics into account. However, we do think it is important to assess students' math ability with independent measures. Downey and Vogt Yuan (2005) found that girls score less well on standardized math tests yet earn better math grades than boys because of their better classroom citizenship. Independent tests provide students with independent information with respect to their abilities.

For finding an adequate estimate of the STEM talent pool our approach led to insightful results. However, a number of limitations are important here. The first limitation is that we did not have independent tests for chemistry and physics at our disposal, which would have strengthened the results. Nevertheless, our results are largely consistent with the findings of Van Langen and Vierke (2006, 2008). The second limitation concerns the criterion used to evaluate our research question. More rigorous criteria lead to smaller percentages of STEM talent than less rigorous ones (Ceci, Williams, & Barnett, 2009). This fact should be taken into account when interpreting our outcomes. We would like to stress that we tried to find the *minimum* percentage of students who could have pursued SCIENCE in addition to those who did choose this profile. Moreover, half of the SCIENCE students group received the label "low math ability", whereas most of these students did pass the FSE. Hence, our approach is a quite conservative one. Based on this argument, the not utilized STEM talent pool is likely to be somewhat larger than the percentages we reported here. Finally, as the educational system in which students choose a study profile is typically Dutch, our results are not easily generalisable to international student samples, this is the third limitation. Nonetheless, the method used in this study can serve as an example for future (international) studies.

The major contribution of the current study is that it gives insight into the percentage of not utilized STEM potential. Our estimates are important for educational practice, because they reduce the size of the target group for focused counselling. It appeared that many students had a reasonable chance of success at the FSE would they have chosen the SCIENCE profile. Making students aware of their abilities prior to their study profile choices could increase students' entry in the SCIENCE profile and subsequently lead to increased student entry in STEM studies in higher education. Moreover, an original contribution made by this study is the use of independent test scores to assess students' math ability. Other studies used course marks (Van Langen & Vierke, 2006, 2008) to examine how many students had sufficient ability to pursue SCIENCE, or used scores on an intelligence test (Mulder, Roeleveld, & Vierke, 2007) to measure underachievement in mathematics.

Since there is a large overlap in math ability among students pursuing different study profiles, further analyses are needed to evaluate which factors influenced students' study profile choice (e.g. Van Langen, 2005). More specifically, insight in the factors that played part in talented students' study profile choice is desirable. Why did some sufficiently able students not choose the SCIENCE profile? They could be unaware of their ability, as students generally choose school subjects in which they feel competent (e.g. Denissen, Zarrett, & Eccles, 2007). From primary education onwards, girls usually have lower levels of competence beliefs in mathematics than boys (e.g. Crombie et al., 2005). Likewise, girls attribute failure in mathematics to lack of capacity whereas boys attribute failure to bad luck or lack of effort. In contrast, girls attribute success in mathematics to good luck whereas boys attribute success to talent (Eccles et al., 1985; Jonsson, 1999; Stipek & Gralinski, 1991; Stokking, 2000; Weiner, 1986). Moreover, math-proficient girls typically prefer non-STEM careers (Ceci et al., 2009).

Additionally, we suggest investigating whether students' choices were influenced by the school and/or significant others (e.g. parents, teachers, peers); see for example Van Langen and Vierke (2009). Teachers' and parents' advices to students might be based on perceived interest rather than on perceived and/or measured ability (e.g. school marks). Educational practitioners should discuss the desired content of these advices. We recommend that all students should be given the opportunity to acquire an objective measure of their (math) ability preceding their study profile choice at the end of the 9th grade, so they can take the results into account when choosing a study profile (and not only base their choice on subjective course marks). This may convince students to take the SCIENCE profile into consideration, or, at least choose advanced mathematics, chemistry, and/or physics more often in addition to their mandatory subjects in the HEALTH, ECONOMY, or CULTURE profile. In our sample, at most 7% of the students in these three profiles chose one or more of the stated subjects in addition to their mandatory subjects. Students usually choose "easy" instead of "hard" subjects as additional subjects, either or not influenced by the school restrictions and/or recommendations. Because the mandatory study profile choice takes place already in the 9th grade, many sufficiently able students leave the STEM pipeline unnecessarily. Their future perspectives narrow and science-oriented studies become unfeasible due to entry restrictions. Our study revealed that approximately 1/4 of the non-SCIENCE boys and almost 1/5 of the non-SCIENCE girls could have pursued SCIENCE but chose other profiles. Hence, the size of the STEM talent pool is promising.

Chapter 3

Are Male Science Students Nerds? Differences in Personality, Social Contacts and Leisure Activities*

Abstract

The focus of this study was whether the stereotyped image of science students as "nerds" corresponds with reality. By using a sample of 1,812 boys in Dutch upper secondary education, we examined differences in personality characteristics, social contacts, and leisure activities between boys pursuing math/science subjects and boys pursuing other school subjects. Results showed that science students have lower scores on the personality factor Extraversion than other students, moreover, small differences were found on the amount of social contacts (i.e. female friends) and time spent on some leisure activities between these students. In addition, the effect of personality, amount of social contacts, and time spent on leisure activities on students' subject choices are investigated. Suggestions for future research are discussed.

* This chapter is based on: Korpershoek, H., Kuyper, H., & van der Werf, M. P. C. (2008). Zijn bèta's nerds? Verschillen in persoonlijkheid, sociale contacten en vrijetijdsbesteding tussen jongens met natuur & techniek en jongens met andere profielen. *Pedagogische Studiën, 85,* 141-156.

Introduction

The Netherlands ranks lower than other European countries in terms of the share of students choosing science subjects in secondary education (Van Langen, 2005). In particular few girls pursue advanced mathematics, chemistry, and physics. This fact led to various studies investigating students' subject choice in the Netherlands (Biermans, Korteweg, & Van Leeuwen, 2004; Research Centre for Education and the Labour Market, 2005, 2006; Second Phase Advisory Point, 2005; Van Langen, 2005; Van Langen, Rekers-Mombarg, & Dekkers, 2006), for example, Van Langen (2005) concluded that next to achievement and educational level, sex and socio-economic status also play a part in explaining students' subject choices, as do their attitudes, like the opinions regarding school subjects and expectations for the future. Moreover, several studies investigated the image of technological education (Willems, 1993), and students' attitudes toward science subjects (among others Alting, 2003; De Klerk Wolters, 1989; Jörg, 1990; Korf, Kamphorst, Jongsma, Van der Werf & Clason, 1986; Otten & Kuyper, 1988; Stokking, 1995). For example, Verhorst and Verhulst (1993) demonstrated that for years, the image has existed that science-oriented studies are boring, uninteresting, and difficult (see also Van der Broek, Kerstens, Hulsen, & Sijbers, 2004; Warps, 2001). On the other hand, the image of science students is still an unexplored research area, whereas this image might be a confounding factor in students' subject choices. In reviewing newspaper articles on this topic, science students were frequently stereotyped as nerds; therefore, the focus of this study was whether this stereotyped image corresponds with reality. After a description of the existing stereotyped images about science students, the relationship between vocational interests and personality is elaborated on. Several studies have demonstrated that vocational interests were connected to personality characteristics, therefore, we consider whether students' subject choices, intended as pre-selection for their study choices in higher education, might partly be explained by students' personality characteristics.

Context

Choosing science and technology in numbers

In 2005, the Research Centre for Education and the Labour Market examined students' interest in science and technology after the study profiles[1] were introduced in the second phase of upper secondary education. This research concerned the study profile choice and study choice of students by means of two student monitors in 1998 and 2003, in which

[1] More information regarding the study profiles can be found in the Method section.

subject choices in 1998 were transformed into study profiles, in order to compare the chosen subjects with study profiles in 2003. Interest in science and technology was defined as choosing the study profile science & technology and/or choosing a science-oriented/technological study. They demonstrated that the interest in science and technology of students in senior general secondary education did not change since the introduction of the study profiles, but that students in pre-university education showed a decreasing interest in science and technology. This decreasing interest was visible in their study profile choice as well as their study choice. Students who did pursue science & technology chose a science-oriented/technological study more often after the introduction of the second phase. The evaluation of the second phase (Second Phase Advisory Point, 2005) showed that 80% of science & technology students continued in a science-oriented/technological study. Biermans, Korteweg, and Van Leeuwen (2004) divided science-oriented studies into "hard" science-oriented studies (for example mathematics, physics, electro-techniques, and engineering) and "soft" science-oriented studies (for example biology, pharmacy, medical science, and biological agriculture), and came to the same conclusion. They reported that 69% of the students in senior general secondary education pursuing science & technology transferred to a hard science-oriented study in higher professional education and 7% to a soft science-oriented study in higher professional education. For students in pre-university education pursuing science & technology, they reported that 59% transferred to a hard science-oriented study at university and that the transfer to a soft science-oriented study at university was 18%. Before the introduction of the second phase, these percentages were clearly lower; 66% of the pre-university students with access to science-oriented studies (students pursuing advanced mathematics and/or physics) actually chose a science-oriented study (Warps, 2001).

Explaining science and technology choice

Prior to choosing a study in higher education, students in Dutch upper secondary education must choose a study profile. Many factors influence students' study profile choice. The most recent explanatory model is that of Van Langen (2005). Van Langen concluded that next to achievement and educational level, sex and socio-economic status also play a part in explaining students' study profile choice, as do their attitudes, like the opinions regarding school subjects and expectations for the future. The role of vocational interests concerning students' subject or study choice has previously been stated by Stokking (1995, 1997). In his literature study, Stokking (1995) showed that many students first choose a study or a profession, and then choose their school subjects. However, Den Boer and Guldemond (1996) showed that when students chose their Final Examination subjects, they were usually led by the question of which subjects they liked most and in which subjects they achieved well. Boys chose their school subjects more often with a continuing education in mind, and girls chose their school subjects more often because they achieved well in these subjects, achieved worse in other subjects, or because they liked these subjects. Apparently, vocational interests were particularly important for boys. However, most students do not have a clear image of their desired future education or occupation when they choose their school subjects (Den Boer & Guldemond, 1996; Kuyper & Guldemond, 1996), and even in the year of their examination many students do not know which studies they want to pursue or which profession they want to practise (Verhorst & Verhulst, 1993). Nowadays, because of the introduction of the study profiles, students must choose a direction at an early stage of their educational career and should be engaged in vocational interests earlier than before.

At the end of secondary school, students can choose a continuing education. Their study choice is in many cases a reflection of their vocational interests. In light of the current study, it is relevant why some students do not choose a science-oriented study. Among others, Verhorst and Verhulst (1993) demonstrated that for years, the image has existed that science-oriented studies are boring, uninteresting, and difficult. In addition, more recent studies showed similar results. Students who did not choose a technological study found other studies more interesting, found science-oriented studies too theoretical and too unidirectional, and found the vocational possibilities with a science-oriented study unattractive (Warps, 2001). These reasons continued to exist with students who did not pursue science-oriented studies after the introduction of the second phase. The student monitor 2003 (Van der Broek, Kerstens, Hulsen, & Sijbers, 2004) showed that next to these reasons, the limited degree of social orientation and the difficulty of science-oriented studies were important. The reasons students reported were not sex-specific, although girls found science-oriented studies too difficult more often than boys.

Theoretical framework

Stereotype images of science students

In newspapers, on television, and in movies, science students are often stereotyped as nerds. We examined this presumed relationship between science students and nerds by means of a literature study. First, we looked at the definition of the word nerd. In the Cambridge Advanced Learner's Dictionary (Walter & Bulhosen, 2008), a nerd is defined as "a person, especially a man, who is unattractive and awkward or socially embarrassing". Although this definition is not scientifically tested, some research has been done on nerds. One of the first studies into stereotype characteristics of nerds is the study of Kinney in 1993. From this study it seemed that in general, students divided themselves into two groups, namely popular/trendy and unpopular/nerdy. According to students, a nerd is characterized by high school achievement, little social skills, and unfashionable clothing. A few years later, Green and Ashmore (1998) examined students' mental images of 4 female types and 4 male types, including the type nerd. With help of content analysis, they made an overview of the mental image students had of a nerd: a nerd is a male, has a weak and unattractive appearance (a thin physique, a slouched posture, and frizzy, greasy hair), is of average height, wears a small amount of jewellery, button-down shirt, pants/jeans, sneakers/casual shoes, and glasses, and is pictured in an academic environment (Green & Ashmore, 1998). In the study of England and Petro (1998), students also had to name their peer groups, and students had to provide characteristics they perceived as associated with each group. These descriptions were divided into 7 groups, for example descriptions of a persons' appearance (looks, clothing style), descriptions of a persons' academics (intelligence, school work, classes, or grades), and descriptions of sociability (interpersonal relations, peer acceptance). These groups were based on prior insights into interactions among peers (England & Petro, 1998). Based on these 7 groups of characteristics, the different types students named were reduced to eight types, among which was the nerd type. Pair wise comparisons showed that nerds differed from (some of the) other types on the following characteristics: academic achievement and academic behaviours (positive difference), sociability and social behaviours (negative difference), athletic (negative difference), and dorky characteristics (positive difference). Moreover, Lubbers (2004) found that extraversion was a strong predictor of peer acceptance.

Kendall (1999) examined the use of the term nerd in an entirely different way, namely by analyzing images of nerds in movies, newspapers, magazines, and on the internet. Her analysis also showed that the image of a nerd was associated with males. Furthermore, she put together a long list of frequently mentioned characteristics of nerds, like enjoying school, does well in school (especially math and science courses), has a high IQ, possesses large amounts of technical knowledge, uses computers frequently, is a media consumer (particularly science fiction), collects objects connected with knowledge (atlases, maps), wears uncoordinated clothing, too short pants, glasses (with ad hoc repairs), has a lack of personal hygiene, has a lack of sports ability, is socially inept, and has a lack of relationships with women. In particular, the exceptional relationship between nerds and computers came up frequently in the investigated images. However, Kendall (1999) demonstrated in her study that the meaning of the concept nerd is liable to change. Since the early eighties a more progressive meaning was lent to the concept, in which stereotype characteristics of nerds were connected to characteristics of working white men from the middle-class. According to Kendall, this shift was related to changes in the economy and future jobs for this group of people. Next to that, more and more people come into contact with computers and other technological equipment in their job or spare time. Kendall stressed that these different views on the concept nerd show that there are differences in approaches between groups of people with different cultural backgrounds. However, a consistent view was that, in general, a nerd referred to someone of the male sex.

Next to the supposed relationship between science students and nerds, we also searched for other specific characteristics of science students. Baron-Cohen, Wheelwright, Skinner, Martin, and Clubley (2001) examined whether students of different disciplines differed in characteristics of the Asperger syndrome/high-functioning autism. For this purpose, they developed a new instrument, namely the Autism Spectrum Quotient (AQ), which indicates where on a scale from normal to autistic a person is located. However, the authors stress that a high score on this test does not mean that someone is autistic, but only that he or she has some autistic characteristics. The study showed that science students (e.g. mathematics, biological science, and medicine) scored significantly higher on this scale than students studying humanities (e.g. classics, law, and history) and students studying the social sciences (e.g. geography, economics, and social sciences). The mathematicians had the highest scores and this was also the case for the winners of the UK Mathematics Olympiad. Science students differed from other students on two of the five investigated areas, namely social skills and imagination. Previous research also showed a connection between characteristics of Asperger syndrome and mathematicians (Baron-Cohen et al., 1998).

Vocational interests and personality

To obtain more insight into the connection between vocational interests and personality, we first examined the measurement of personality and of vocational interests. Research shows that personality can be described in five large domains, also called the Big-Five factor structure (Goldberg, 1993). Within each factor, several facets of personality are distinguished. In the research field, scholars agreed upon the interpretation of four factors: extraversion, agreeableness, conscientiousness, and emotional stability (or inverse neuroticism). They do not agree upon the name and replicability of the fifth factor (Hendriks, 1997). A commonly used label is openness to experience, for example in the Revised NEO Personality Inventory (NEO-PI-R; Costa & McCrae, 1992). In the Dutch version of the FFPI-personality questionnaire the fifth factor is labelled as autonomy (Hendriks, 1997).

Although there is an abundance of vocational interest tests, in scientific research the vocational interest test (Self-Directed Search questionnaire) of Holland is often used (most recent description: 1997), also called the Big Six. The six factors of the Big Six are often indicated as RIASEC and stand for realistic, investigative, artistic, social, enterprising, and conventional interests. The relationship between vocational interests and personality has frequently been examined by calculating correlations between the Big Five and the Big Six. Four relationships between personality and vocational interests were found consistent. It concerns the relationships between extraversion and social and enterprising interests and between openness to experience and artistic and investigative interests (Barrick, Mount, & Gupta, 2003; Costa, McCrae, & Holland, 1984; Gottfredson, Jones, & Holland, 1993; Harris, Vernon, Johnson, & Jang, 2006; Larson, Rottinghaus, & Borgen, 2002; Mount, Barrick, Scullen, & Rounds, 2005). The consistency of these relationships was demonstrated in the review of Tokar, Fischer, and Subich (1998) and was practically similar for males and females (De Fruyt & Mervielde, 1997; Larson et al., 2002; Tokar & Swanson, 1995), except for the relationship between openness to experience and investigative interests. Tokar and Swanson (1995) and Schinka, Dye, and Curtiss (1997) found this relationship only for females, De Fruyt and Mervielde (1997) only for males, and Schinka et al. (1997) for both males and females. Inconsistency also applies to other (weaker) relationships, for example the relationship between conscientiousness and conventional interests (among others Barrick et al., 2003; De Fruyt & Mervielde, 1997; Gottfredson et al., 1993; Harris et al., 2006), and the relationship between agreeableness and social interests (among others Barrick et al., 2003; Harris et al., 2006). Despite large differences in relationships between personality and vocational interests, similarities are clear. The personality factor extraversion consistently correlates with social and enterprising interests and the personality factor openness to experience consistently correlates with artistic and investigative interests.

In the current paper, we examined students' subject choices as the pre-choice of profession. The relationship between personality and subject choices is still a poorly examined research area. In one of the few studies in this area a negative relationship was found between extraversion and students' choice of a math/science major (Lapan, Shaughnessy, & Boggs, 1996), in other words, mathematics students were more introverted than other students. However, relationships between other personality factors and students' subject choices in secondary education (e.g. advanced mathematics, chemistry, and physics) or students' study choice in higher education (e.g. science-oriented studies) were not found.

Research questions

Based on the research literature, we expected to find several differences between science students and other students. We defined science students as students who pursued advanced mathematics, chemistry, and physics in upper secondary education (an elucidation of this choice can be found in the next paragraph). Although investigating students' appearance and measuring students' autistic characteristics were beyond our research possibilities, information was available on personality characteristics, social contacts, leisure activities, and students' sex to test the earlier mentioned stereotype images of science students. In prior research, student achievement (especially in mathematics) was also determined as part of the stereotyped image of science students as nerds, but due to high correspondence between pursuing math/science and students' mathematics achievement, this aspect was omitted. Based on our literature review, we formulated the following hypotheses:

1. Science students have lower scores on the personality factor *Extraversion* than other students.
2. Science students have less social contacts than other students.
3. Science students spent more time using a computer and other media than other students.
4. Science students spent less time on sports, relationships, and social contacts than other students.

In addition, we examined whether science students differed from other students in the personality factors *Agreeableness, Conscientiousness, Emotional Stability,* and *Autonomy*, and we examined the predictive value of personality characteristics, leisure activities, and social contacts on students' subject choices (i.e. choosing math/science subjects or not). The effects of personality characteristics on students' choices in education are to a large extent unknown.

Method

Participants

We used data from the so-called VOCL-cohort study (in Dutch: "Voortgezet Onderwijs Cohort Leerlingen") in which data was collected by the GION institute in cooperation with Statistics Netherlands. A description of this cohort study can be found in Kuyper, Lubbers, and Van der Werf (2003). To a large extent, this cohort is a representative reflection of the national population of students and schools in secondary education. The participants in our sample were students from Dutch upper secondary education (senior general secondary education and pre-university education). Furthermore, this study only included boys because literature showed that the term nerd normally implies males. This selection resulted in 2,454 students of which 74% had responded to the questionnaires used in this study (see paragraph 4.2). The results were based on the latter group (1,812 boys) which consisted of 812 students in senior general secondary education (hereafter called track B) and 1,000 students in pre-university education (hereafter called track A). Non-response analyses showed that the response group was representative for boys in Dutch upper secondary education concerning their socio-economic status, but in the response group native Dutch students with a high intake level were slightly overrepresented.

At the end of the 9th grade, the students chose one out of four possible combinations of school subjects, called "study profiles". Next to science & technology (SCIENCE), students can choose science & health (HEALTH), economics & society (ECONOMY), or culture & society (CULTURE), or a combination of two profiles. Besides subjects that are common in all profiles (e.g. Dutch and English language), SCIENCE and HEALTH students take their Final School Examination (FSE) in advanced mathematics, chemistry, and physics, although in the HEALTH profile the time spent on these subjects is much less since the content of this profile is more elementary and less science-oriented. The HEALTH profile also includes biology. The ECONOMY and CULTURE profiles roughly consist of history (both), economics (ECONOMY), and modern languages (CULTURE). In this paper, we made a distinction between science students and other students. Although the HEALTH profile also consists of math/science subjects (albeit in lesser extent), only students pursuing SCIENCE were counted as science students. The SCIENCE profile prepares students best for "hard" science-oriented studies in higher education, while the HEALTH profile prepares for more "soft" science-oriented studies (e.g. Biermans et al., 2004). Moreover, the SCIENCE profile is, to a large extent, pursued by boys only, therefore the "nerdy" image seems to apply to the SCIENCE students in particular. In addition, from VOCL-data it was found that students pursuing HEALTH had significantly lower scores on prior measured mathematical ability (an arithmetic test, a mathematical test and the symbolic part of an intelligence test) than students pursuing SCIENCE. Therefore, we defined science students as students pursuing SCIENCE, and students pursuing HEALTH, ECONOMY, or CULTURE as other students. Of the boys in track B, 26% pursued SCIENCE, as did 29% of the boys in track A.

Variables and instruments

Three research instruments were used, measuring students' personality characteristics, social contacts, and leisure activities.

Personality characteristics. Personality was measured with the Five-Factor Personality Inventory (Hendriks, 1997; Hendriks, Kuyper, Offringa, & Van der Werf, 2008). This questionnaire consisted of 100 items and was included in the 9th grade questionnaire of VOCL'99 (Kuyper & Van der Werf, 2005). In an earlier stage, these items were used to construct scores on the personality factors of the Big Five. These factors are *Extraversion, Agreeableness, Conscientiousness, Emotional Stability,* and *Autonomy.*

Social contacts. Social contacts of students were measured with two questions addressed in a questionnaire of VOCL'99, administered in the 11th grade (Korpershoek, Kuyper, & Van der Werf, 2006). These questions were: "How many good male friends do you have?" and "How many good female friends do you have?" The response categories were: none (scored 0), 1 or 2 (scored 1), 3 or 4 (scored 2), 5 or 6 (scored 3), 7 or 8 (scored 4), 9 or 10 (scored 5), and more than 10 (scored 6). The averages used in the results section refer to these categories.

Leisure activities. Leisure activities were also measured in the VOCL'99 questionnaire that was administered in the 11th grade (Korpershoek et al., 2006). Students were asked to fill out how much time per week (on average) they spend on ten different leisure activities (reading, television, computer, sports, go out, meeting friends, relationship, family activities, housekeeping, and a job). Unlikely high numbers (i.e. >25) were truncated to 25 hours, resulting in a response range of 0 to 25 hours per activity.

Results

Successively, we discuss the descriptive results, the hypotheses testing, and the prediction of students' study profile choice.

Descriptive results

Science students and other students – in other words, boys pursuing the science & technology profile and boys pursuing other profiles – were compared on personality characteristics, social contacts, and leisure activities. Table 1 gives an overview of the means and standard deviations of five personality factors, the average number of (fe)male friends, and the average amount of time spend per leisure activity, as filled out by the students. The table shows results for both tracks, separately for science students and other students.

Small differences were found between science students and other students on Extraversion, the number of female friends, and on most leisure activities. Students from track A and B differed on for example the amount of time they spend on going out, and on a job. In the next paragraph, the differences were tested and described further. The correlations between the examined variables were small. The correlations between social contacts and leisure activities on the one side and personality factors on the other side were at most 0.29. The two social contacts variables (the number of male and female friends) correlated moderately, namely 0.53.

Testing hypotheses

Differences between science students and other students on personality characteristics, social contacts, and leisure activities were tested with univariate analyses of variance, with science students/other students and track B/track A as independent variables. Tables 2, 3, and 4 represent the results of these analyses. First, we analyzed differences in personality characteristics between science students and other students (and between students in track B and students in track A).

Table 1 *Means and standard deviations (between brackets) on personality factors, number of (fe)male friends and leisure activities*

	Track A		Track B	
	Science students[a]	Other students[b]	Science students[a]	Other students[b]
Extraversion	0.7 (1.0)	1.0 (0.9)	0.6 (0.8)	1.1 (0.9)
Agreeableness	1.6 (0.9)	1.6 (1.0)	1.4 (1.0)	1.4 (1.1)
Conscientiousness	0.2 (1.2)	0.2 (1.2)	0.2 (1.2)	0.1 (1.1)
Emotional stability	1.5 (0.8)	1.4 (0.8)	1.5 (0.9)	1.5 (0.8)
Autonomy	0.8 (0.9)	0.8 (0.9)	0.6 (0.7)	0.8 (0.9)
Number of male friends[c]	3.5 (1.5)	3.6 (1.6)	3.5 (1.6)	3.6 (1.7)
Number of female friends[c]	1.8 (1.5)	2.2 (1.7)	1.9 (1.6)	2.2 (1.7)
Reading[d]	2.5 (2.6)	2.2 (2.6)	2.3 (2.9)	2.0 (2.4)
Television[d]	8.0 (5.7)	9.2 (6.3)	8.3 (5.7)	8.9 (6.5)
Computer[d]	9.3 (6.3)	8.7 (5.8)	9.0 (7.1)	9.1 (6.1)
Sports[d]	4.8 (3.7)	5.5 (4.2)	4.6 (3.4)	5.4 (4.5)
Go out[d]	3.1 (3.3)	4.1 (3.2)	4.2 (4.1)	4.8 (3.7)
Meeting friends[d]	7.4 (6.3)	8.2 (6.5)	7.7 (5.7)	8.5 (6.2)
Relationship[d]	1.7 (4.4)	2.1 (4.8)	1.6 (4.2)	3.2 (6.2)
Family activities[d]	3.8 (4.0)	4.4 (4.5)	3.9 (4.5)	4.4 (4.1)
Housekeeping[d]	2.1 (2.3)	2.3 (2.4)	2.0 (2.1)	2.5 (2.4)
Job[d]	4.7 (4.8)	5.2 (4.8)	5.8 (5.2)	6.7 (5.7)

Notes. [a] Students pursuing SCIENCE; [b] Students pursuing HEALTH, ECONOMY, or CULTURE; [c] Categories: 0 = none, 1 = 1 or 2 friends, 2 = 3 or 4 friends, 3 = 5 or 6 friends, 4 = 7 or 8 friends, 5 = 9 or 10 friends, and 6 = more than 10 friends; [d] In hours.

Science students significantly differed from other students on the factors Extraversion, Emotional Stability, and Autonomy. On average, science students had lower scores on Extraversion and Autonomy and higher scores on Emotional Stability. The effect sizes (*partial eta squared*; Cohen, 1988) of the difference in Extraversion was moderate, and the effect sizes of the other differences were very small. In addition, we found a significant difference between the two tracks on Agreeableness: on average, students from track A had higher scores on this variable than students from track B (a small difference). Finally, we found a significant interaction effect between science students/other students and track on Autonomy. This indicated that the effect of science students/other students on Autonomy was different for students from the different tracks. Table 1 showed that science students in track B, on average, had lower scores on Autonomy than the other three groups. However, the interaction effect was very small. Subsequently, we examined differences in the number of male and female friends (see Table 3).

Table 2 *Analyses of variance on personality factors with track (A/B) and study profile (science students versus other students)*

	F	df	p-value	Partial eta-squared
Extraversion				
Profile [a]	48.25	1, 1431	0.00***	0.03
Track	0.03	1, 1431	0.44	0.00
Profile x Track	0.56	1, 1431	0.23	0.00
Agreeableness				
Profile	0.13	1, 1419	0.72	0.00
Track	9.17	1, 1419	0.00**	0.01
Profile x Track	0.15	1, 1419	0.70	0.00
Conscientiousness				
Profile	1.68	1, 1432	0.20	0.00
Track	0.68	1, 1432	0.41	0.00
Profile x Track	0.35	1, 1432	0.55	0.00
Emotional stability				
Profile	5.41	1, 1431	0.02*	0.00
Track	0.14	1, 1431	0.71	0.00
Profile x Track	0.20	1, 1431	0.65	0.00
Autonomy				
Profile	5.17	1, 1429	0.02*	0.00
Track	2.48	1, 1429	0.12	0.00
Profile x Track	5.98	1, 1429	0.01*	0.00

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$; [a] One-tailed test.

Table 3 *Analyses of variance on number of (fe)male friends with track (A/B) and profile (science students versus other students)*

	F	df	p-value	Partial eta-squared
Number of male friends				
Profile[a]	1.09	1, 1006	0.15	0.00
Track	0.13	1, 1006	0.36	0.00
Profile x Track	0.01	1, 1006	0.46	0.00
Number of female friends				
Profile[a]	25.80	1, 1006	0.00*	0.01
Track	1.22	1, 1006	0.25	0.00
Profile x Track	0.41	1, 1006	0.35	0.00

Notes. * $p < .01$; [a] One-tailed test.

Table 4 *Analyses of variance on leisure activities with track (A/B) and profile (science students versus other students)*

	F	df	p-value	Partial eta-squared
Reading				
Profile[a]	2.12	1, 1003	0.04*	0.00
Track	0.92	1, 1003	0.17	0.00
Profile x Track	0.10	1, 1003	0.37	0.00
Television				
Profile[a]	3.94	1, 1003	0.02*	0.00
Track	0.00	1, 1003	0.48	0.00
Profile x Track	0.44	1, 1003	0.25	0.00
Computer				
Profile[a]	0.46	1, 1003	0.25	0.00
Track	0.01	1, 1003	0.46	0.00
Profile x Track	0.64	1, 1003	0.21	0.00
Sports				
Profile[a]	6.00	1, 1003	0.01**	0.01
Track	0.24	1, 1003	0.31	0.00
Profile x Track	0.03	1, 1003	0.43	0.00
Go out				
Profile[a]	10.29	1, 1003	0.00***	0.01
Track	13.18	1, 1003	0.00***	0.01
Profile x Track	0.25	1, 1003	0.31	0.00
Meeting friends				
Profile[a]	3.07	1, 1003	0.04*	0.00
Track	0.41	1, 1003	0.26	0.00
Profile x Track	0.01	1, 1003	0.46	0.00
Relationship				
Profile[a]	7.21	1, 1003	0.00**	0.01
Track	1.84	1, 1003	0.09	0.00
Profile x Track	2.05	1, 1003	0.08	0.00
Family activities				
Profile	2.85	1, 1003	0.09	0.00
Track	0.07	1, 1003	0.79	0.00
Profile x Track	0.01	1, 1003	0.93	0.00
Housekeeping				
Profile	4.18	1, 1003	0.04*	0.00
Track	0.10	1, 1003	0.75	0.00
Profile x Track	0.78	1, 1003	0.38	0.00
Job				
Profile	3.97	1, 1003	0.05*	0.00
Track	13.01	1, 1003	0.00***	0.01
Profile x Track	0.23	1, 1003	0.63	0.00

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$; [a] One-tailed test.

Table 3 shows a significant difference between science students and other students concerning the number of female friends. On average, science students had less female friends, but this was only a small effect. There was no difference between science students and other students in the number of male friends. Additionally, students from track B and A did not differ in their number of (fe)male friends (and the interaction in both cases was also not significant). Next, we examined students' leisure activities.

Table 4 shows significant differences between science students and other students concerning reading, watching television, play sports, going out, meeting friends, a relationship, housekeeping, and a job. Science students spend more time on reading and less time on the other activities than other students. Furthermore, we found significant differences between the tracks concerning the number of hours spent on going out and a job. Students from track B spend more time on these activities than students from track A, but the differences were (very) small. We did not find significant differences concerning the time spent on a computer or family activities, and moreover no significant interaction effects.

Predicting students' study profile choice

Finally, the predictive value of the examined variables was examined by predicting students' study profile choice. For both tracks, we explored which variables contributed to the explanation of pursuing science & technology or not. For this purpose, logistic regression analyses were performed, with three groups of predictors, namely personality factors, social contacts, and leisure activities. The criterion variable in these analyses was the chosen profile with two categories, namely: (1) science & technology, and (2) science & health, economics & society, or culture & society, for which the second category was logically chosen as reference group. Table 5 gives an overview of the results for both tracks.

First we look at the results for students from track B. The empty model (not included in the table) included just a constant. The corresponding regression coefficient for this constant was 0.99, which means that the probability of pursuing science & technology was $1 / (1 + e^{0.99}) = 27\%$. This percentage (almost) corresponds with the percentage of boys from track B pursuing science & technology. The probability of pursuing another profile was $e^{0.99} / (1 + e^{0.99}) = 73\%$. This led to an odds ratio of $0.73 / (1 - 0.73) = 2.70$. Consequently, the probability of pursuing another profile was 2.70 times larger than the probability of pursuing science & technology. When personality factors were included in Model 1, the fit of the model improved significantly ($\chi2$ [5] = 18.72, $p < 0.01$). Only Extraversion showed a significant effect, and the model explained 11% of the variance (Nagelkerke R^2). Adding social contacts in Model 2 did not improved the fit of the model ($\chi2$ [7] = 18.75, $p < 0.01$), nor did leisure activities in Model 3 ($\chi2$ [17] = 31.04, $p < 0.05$).

Table 5 *Logistic regression on study profile choice (science & technology or not) for students from track B (N=233) and students from track A (N=395)*

	Track A		Track B	
	B (SE)	*exp b*	*B (SE)*	*exp b*
Constant	0.06 (0.51)	1.06	0.03 (0.72)	1.03
Extraversion	0.44 (0.14)**	1.55	0.57 (0.19)**	1.77
Agreeableness	0.07 (0.12)	1.07	0.13 (0.20)	1.14
Conscientiousness	0.04 (0.10)	1.04	-0.02 (0.17)	0.98
Emotional stability	-0.24 (0.15)	0.78	0.02 (0.19)	1.02
Autonomy	-0.12 (0.14)	0.89	0.36 (0.21)	1.44
Male friends	-0.07 (0.09)	0.94	0.02 (0.13)	1.03
Female friends	0.18 (0.09)*	1.20	-0.04 (0.12)	0.96
Reading	0.02 (0.05)	1.02	-0.10 (0.06)	0.90
Television	0.03 (0.02)	1.03	0.03 (0.03)	1.04
Computer	-0.02 (0.02)	0.98	-0.05 (0.03)	0.95
Sports	-0.01 (0.03)	0.99	-0.03 (0.04)	0.97
Go out	0.05 (0.04)	1.06	-0.03 (0.04)	0.97
Meeting friends	-0.00 (0.02)	1.00	0.02 (0.03)	1.02
Relationship	-0.01 (0.03)	0.99	0.00 (0.03)	1.00
Family activities	0.05 (0.03)	1.05	0.04 (0.04)	1.04
Housekeeping	0.02 (0.05)	1.03	0.06 (0.08)	1.06
Job	0.03 (0.03)	1.03	0.05 (0.03)	1.05

Note. * $p < .05$, ** $p < .01$.

The final model (Model 3) explained 18% of the variance (Nagelkerke R^2). Extraversion was the only significant predictor of pursuing science & technology. In the final model, the regression coefficient of Extraversion was 0.57 with an odds ratio of $e^{0.57} = 1.77$. The odds ratio in the empty model was 2.70, therefore the new odds ratio of pursuing science & technology was 2.70 * 1.77 = 4.78. This resulted in a probability of pursuing a profile other than science & technology of 4.78 / (1 + 4.78) = 83%. In other words, the probability of pursuing a profile other than science & technology increased by 10% when a students' score on the factor Extraversion increased by one unit.

The results for students from track A were as follows. The regression coefficient of the constant was 0.83, therefore the probability of pursuing science & technology was 1 / (1 + $e^{0.83}$) = 30%. Again, this percentage (almost) matched the percentage of boys from track A pursuing science & technology. The probability of pursuing another profile was $e^{0.83}$ / (1 + $e^{0.83}$) = 70%. The odds ratio was 0.70 / (1 - 0.70) = 2.33. So, the probability of pursuing a profile other than science & technology was 2.33 times larger than the probability of pursuing science & technology. Adding the personality factors in Model 1 did improve the fit of the model significantly ($\chi 2$ [5] = 21.22, $p < 0.001$). Once more, only the factor Extraversion had a significant effect. The model explained 7% of the variance (Nagelkerke R^2). The fit of the model did not improve when social contacts were added in Model 2 ($\chi 2$ [7] = 25.86, $p < 0.001$), however, on top of the significant effect of Extraversion, the number of female friends had a significant effect. Adding the leisure activities in Model 3 did not improve the fit of the model ($\chi 2$ [17] = 36.22, $p < 0.01$) and showed no new significant predictors. The final model (Model 3) explained 12% of the variance (Nagelkerke R^2) with the variable Extraversion and the number of female friends as significant predictors for pursuing science & technology. In this final model, the regression coefficients of Extraversion and the amount of female friends were 0.44 and 0.18 respectively, with odds ratios of $e^{0.44} = 1.55$ and $e^{0.18} = 1.20$. The odds ratio in the empty model was 2.33. When we added Extraversion as a predictor, the new odds ratio was 2.33 * 1.55 = 3.61. The probability of pursuing a profile other than science & technology was 3.61 / (1 + 3.61) = 78%. This means that the probability of pursuing a profile other than science & technology increased by 8% when a students' score on the factor Extraversion increased by one unit. Adding the number of female friends as a predictor resulted in an odds ratio of 2.33 * 1.20 = 2.80, and therefore the probability of pursuing a profile other than science & technology was 2.80 / (1 + 2.80) = 74%. In other words, the probability of pursuing a profile other than science & technology increased by 4% when a student scored one category higher on the variable number of female friends.

In conclusion, we can state that the prediction of pursuing science & technology, based on personality characteristics, social contacts, and leisure activities of students, was limited. The models had low predictive value, however, Extraversion evolved as a significant predictor for both tracks, and for track A the number of female friends was also a significant predictor of students' study profile choice.

Conclusions and discussion

In this study, we focused on the stereotyping of science students as nerds. Our results showed some significant differences between science students (in this study: boys pursuing the SCIENCE profile in Dutch upper secondary education) and other students (boys pursuing one of the other profiles: HEALTH, ECONOMY, or CULTURE). Part of these differences corresponded to our expectations based on literature, which we tested with four hypotheses. The first hypothesis (science students have lower scores on the personality factor Extraversion than other students) was confirmed. Science students indeed scored lower on the personality factor Extraversion than other students. The second hypothesis (science students have less social contacts than other students) was confirmed only for students from track A, and only for the number of female friends. Science students from track A had less female friends than other students, but this was not the case for male friends. The third hypothesis (science students spent more time using a computer and other media than other students) could not be confirmed. Science students did spent more time reading, but they did not spent more time using a computer, and spent even less time watching television than other students. For these aspects, the stereotype image of science students as nerds could not be confirmed. Finally, the fourth hypothesis (science students spent less time on sports, relationships, and social contacts than other students) was confirmed, though the differences between science students and other students were in general (very) small. In particular the personality-differences we found among students pursuing different school subjects confirm the instinctive idea which some students have; math/science simply does not "fit" them. Stimulating for example introverted students to pursue the science & technology profile might therefore be more effective than trying to convince extraverted students to pursue a math/science career. Future research is needed to investigate whether these personality differences persist in higher education (e.g. science-oriented studies versus other studies).

In addition to the results described above, we found several other differences between science students and other students. First, science students scored higher on Emotional Stability than other students. Second, we found that science students spent less time per week on house keeping and a job than other students. These differences were negligible (effect size .00). Moreover, we found some differences between students from track B and students from track A. Students from track A scored higher on Agreeableness than students from track B. A small positive relationship between educational level and Agreeableness was also found by Hendriks, Kuyper, Offringa, and Van der Werf (2008). However, since students from track A with a high intake level were overrepresented in the response group, it is also be possible that students who scored high on Agreeableness were more willing to fill out the questionnaire, by which students who scored high on Agreeableness might be overrepresented. In addition to differences on Agreeableness between students from the two tracks, science students from track B scored lower on Autonomy than other students, although the difference was negligible. Finally, we found that students from track A spend less time on going out and on a job than students from track B. Besides possible other priorities of these students, students from track A might have less leisure time than students from track B due to school and homework. In addition to the previously mentioned overrepresentation of students from track A with a high intake level in our sample, native Dutch students were also overrepresented. However, up to now, no information is available about differences between native Dutch students and students from ethnic minority groups concerning the influence of personality, social contacts, and leisure activities on study profile choice.

This paper took a first step in investigating the effect of personality characteristics on students' choices in education. From additional analyses, it was confirmed that the prediction of pursuing SCIENCE, based on personality characteristics, social contacts and leisure activities of the students, was limited. The regression models had low predictive value, but in spite of this, for both tracks Extraversion was a significant predictor, and the number of female friends was a significant predictor for students from track A concerning students' study profile choice. Obviously, the predictive value of the models would increase when for example mathematics achievement was added as predictor, but the purpose of these analyses was just to examine the predictive value of personality characteristics, social contacts, and leisure activities on pursuing SCIENCE or not, and not to create an optimally predictive model. Furthermore, in the current study, social contacts and leisure activities of the students were measured in the 11th grade, while the study profile choice had taken place at an earlier point in time. Therefore, the "prediction" of study profile choice from these variables is somewhat contradictory given the positioning in time. Next to that, we did not ask students directly about their stereotype images of science students or whether these images influenced their study profile choice.

In closing, we showed that the stereotyping of male science students as nerds was only partly well-founded. Most characteristics of nerds from the research literature could not be confirmed for boys pursuing SCIENCE. Moreover, discovered differences between science students and other students were (very) small. All in all, this paper argues that students should not worry about becoming a nerd when pursuing SCIENCE, although others (undeservedly) still image them that way. Future research will have to reveal whether students were actually influenced by their own stereotype images of science students or the stereotype images of others when choosing a study profile or a study in higher education.

Chapter 4

Who "Fits" the Science & Technology Profile? Personality Differences in Secondary Education*

Abstract

The present study explores the relationship between personality characteristics and students' subject choice in secondary education and addresses the question: "Are there differences in personality characteristics among students choosing different school subjects?" The research included 3,992 9th grade students. We used the Five-Factor Personality Inventory (FFPI) of Hendriks, Hofstee, and De Raad (1999a) to measure students' personality. With respect to all five personality factors our results show significant differences among students who chose different sets of subjects. We observed that students who took advanced mathematics, chemistry, and physics were less extraverted and more conscientious than students who chose a less science-oriented set of subjects. The results confirm that students' interests and, consequently, their subject choices are related to their personality.

* This chapter is based on: Korpershoek, H., Kuyper, H., van der Werf, M. P. C., & Bosker, R. J. (2010). Who 'fits' the science & technology profile? Personality differences in secondary education. *Journal of Research in Personality, 44,* 649-654.

Introduction

Personality is related to various aspects of students' attitudes and behaviour in educational settings (see Tokar, Fischer, & Subich, 1998), for example to educational aspiration (Gasser, Larson, & Borgen, 2004), learning style (Busato, Prins, Elshout, & Hamaker, 1999) or strategy (Bidjerano & Dai, 2007), and school achievement (Lounsbury, Sundstrom, Loveland, & Gibson, 2003; O'Connor & Paunonen, 2007). There is, for instance, a tendency towards extraversion to be negatively associated with scholastic achievement in terms of students' grade point average (O'Connor & Paunonen, 2007) and undergraduates' achievement in statistics (Furnham & Chamorro-Premuzic, 2004). In contrast, conscientiousness correlates positively with scholastic achievement (De Fruyt & Mervielde, 1996; Furnham & Chamorro-Premuzic, 2004; Laidra, Pullmann, & Allik, 2007; O'Connor & Paunonen, 2007).

Despite the numerous studies that investigate the role of personality in educational contexts, few studies are focussed on the relationship between personality and students' subject choices in secondary education. Because students' interests are related to their educational and career choices (Boone, Van Olffen, & Roijakkers, 2004; Elsworth, Harvey-Beavis, Ainley, & Fabris, 1999; Rosenbloom, Ash, Dupont, & Coder, 2008), it is reasonable to assume that their subject choices are related to their personality. One might expect that students are attracted to school subjects that provide them with career perspectives that in their perception "fit them" (and thus, implicitly, fit their personality; De Fruyt & Mervielde, 1996). According to the theory of Holland (1997), vocational interests are an expression of personality. Holland claims that six interest types explain people's vocational preferences: *realistic, investigative, artistic, social, enterprising,* and *conventional* interests (RIASEC), also called the Big Six. The theory assumes that people select environments in which they can express their interests and that these environments are influenced by the people within them. In the same vein one might expect that people select environments that fit their personality, for example, students who have specific educational preferences (e.g. math classes).

Most studies addressing the relationship between personality and vocational interests use the Big-Five factor structure of Goldberg (1993) to categorise personality into five large domains: *extraversion*, *agreeableness*, *conscientiousness*, *emotional stability* (or inverse *neuroticism*), and *openness to experience* (NEO-PI-R; Costa & McCrae, 1992) or *autonomy* (FFPI; Hendriks, Hofstee, & De Raad, 1999a). Consistent evidence has been found for four relationships: the personality factor *extraversion* is related to *social* and *enterprising* interests and the personality factor *openness to experience* to *artistic* and *investigative* interests (e.g. Larson, Rottinghaus, & Borgen, 2002). Although boys and girls differ to some extent in personality (e.g. Costa, Terracciano & McCrae, 2001; Feingold, 1994; Goldberg, Sweeney, Merenda, & Hughes, 1998), these relationships are almost similar for these groups (De Fruyt &

Mervielde, 1997; Larson et al., 2002; Tokar & Swanson, 1995). All in all, the results suggest that personality and students' interests in secondary education are somehow related.

The subject choices that students make in secondary education are important decisions, because they limit the options in entering specific studies in higher education. This is why students receive advice from counsellors, teachers, and parents. Subject choice is influenced by many factors, namely (1) ability, (2) background characteristics (e.g. sex, socioeconomic status, and ethnicity), (3) perceived difficulty of specific school subjects and the expectations with respect to success in these subjects, and (4) attitudes towards specific school subjects, for example towards science-related domains (for an overview see Van Langen, 2005). Most of the studies in this field try to explain why so few girls choose mathematics/science (e.g. Eccles et al., 1985, Eccles, 1987, 2005; Van Langen, 2005). Unfortunately, many students drop mathematics and science subjects as soon as these subjects become optional (Organisation for Economic Co-operation and Development, 2009). Consequently, after making this choice it is practically impossible to consider a career in Science, Technology, Engineering, or Mathematics (the so-called STEM discipline). Although it is recognised that students choose subjects that "fit them", the importance of personality in their subject choice is, however, still unclear. Some personality traits might be more suitable for particular disciplines while other traits might be more suited for other fields (De Fruyt & Mervielde, 1996). This is usually a subjective assessment of the counsellor and/or the student. Therefore, we present a more objective approach by investigating students' personality characteristics. Considering the importance of subject choices for students' career possibilities, we argue that a further investigation of the fit between personality characteristics and school subjects is evident.

The present study

The idea that personality is systematically related to subject choice in secondary education inspired us to further explore this relationship. The present paper seeks to address the following question:

Are there differences in personality characteristics among students choosing different school subjects?

This work aims at increasing the understanding of personality differences among students by exploring whether the underlying assumption of Holland's theory (i.e. vocational interests are an expression of personality) applies to students' subject choices in the Dutch secondary education. We applied students' self-ratings to the Dutch version of the Five-Factor Personality Inventory (FFPI) of Hendriks et al. (1999a; see also Hendriks, Kuyper, Offringa, & Van der Werf, 2008). Although personality is not yet fully developed at age 15 (Klimstra, Hale, Raaijmakers, Branje, & Meeus, 2009; Pullmann, Raudsepp, & Allik, 2006), studying this group has increased our understanding of personality differences occurring already at an early age among students with different interests. Investigating students' personality characteristics may provide us with insight into which students "fit" particular school subjects (e.g. math/science), which could serve as supplementary information for educational practitioners and counsellors in advising these students.

The Dutch educational context. In the Netherlands, students enter secondary education (7th grade) at age 12 or 13. Based on their previous achievements and the primary school teacher's recommendation, students enter one of three basic tracks: preparatory secondary vocational education (track C), senior general secondary education (track B), or pre-university education (track A). Track C (the lowest track, duration 4 years) prepares students for senior secondary vocational education, of which the highest level is 4 (post-secondary non-tertiary education) according to the 1997 International Standard Classification of Education (ISCED97). Tracks A and B prepare students for tertiary education; track B (the middle track, duration 5 years) for higher professional education and track A (the highest track, duration 6 years) for university. Both forms of higher education belong to level 5a of ISCED97. They each cover around 20 percent of the overall student population in the Netherlands.

At the end of the 9th grade, students in track A and B have to choose one of four possible combinations of school subjects, called "study profiles". In addition to science & technology (SCIENCE), they can choose science & health (HEALTH), economics & society (ECONOMY), or culture & society (CULTURE), or a combination of two profiles. Besides Dutch and English, which are common in all profiles, the SCIENCE and HEALTH subjects included in the Final School Examinations (FSE) are advanced mathematics, chemistry, and physics. Less time is spent on these subjects in the HEALTH profile, since it is more elementary and less science-oriented. This profile also includes biology. The ECONOMY and CULTURE profiles roughly consist of applied mathematics (both), history (both), economics (ECONOMY), and modern languages (CULTURE). Formally, the study profile choice is unrestricted and mainly based on students' interests and ambitions. Meanwhile, students' aspirations can be restricted to some extent due to their prior performance on particular subjects or the negative advice of parents, teachers, and school counsellors.

Hypotheses. Given the exploratory nature of the study, we only formulated one specific research hypothesis regarding the relationships between personality and study profile choice. We expected a negative association between extraversion and the choice of advanced mathematics and science courses. This expectation followed the results of Lapan, Shaughnessy, and Boggs (1996), who report a negative relationship between extraversion and choosing math/science, which means that mathematics students appear to be more introverted than other students. Since Wolf and Ackerman (2005) point out that more gifted students become more introverted over time, and a prior analysis of our sample indicated that students choosing SCIENCE had, on average, higher scores on math ability than those who opted for other subjects, we expected to find this association in our student sample as well.

In addition, two issues merit extra attention. Firstly, a number of studies indicate significant personality differences in gender. On average, girls score higher on extraversion and agreeableness and lower on emotional stability than boys (e.g. Hendriks et al., 2008). Therefore, we additionally examined sex-differences in the relationship between study profile choice and personality characteristics. Secondly, there were large math ability differences among the study profile groups in our sample. To control for the effect of this variable, we included students' math ability in the analyses.

Method

Participants

The present study was conducted in the two highest tracks of the Dutch secondary education and included 3,992 students in the 9th grade (average age: 15 years), of which 1,775 were boys (44%) and 2,217 girls (56%). The data used formed part of a large-scale longitudinal study in the Netherlands, the "Cohort Studies in Secondary Education" (VOCL'99). In the VOCL'99 study, students were being followed in their educational career from the 7th grade onwards until they had completed their full-time education. The schools administered standardized tests in the first three cohort years to assess the students' intelligence and achievements in the Dutch language and mathematics. In addition, extensive questionnaires were used throughout the study, addressing topics such as motivation, learning styles, personality, and aspirations. The overall VOCL'99 sample is quite representative of the schools and students in Dutch secondary education (Kuyper & Van der Werf, 2003). With respect to socioeconomic status the selected sample of 3,992 students corresponded with the overall student sample of tracks A and B (of VOCL'99). Girls were slightly overrepresented (56% versus 52%) and students from ethnic minority groups slightly underrepresented (13% versus 19%). Since these differences are small, we did not expect them to have a large impact on our results. The study profile choices were representative of those in the entire Dutch student population. For more information on the VOCL'99 study, please see Kuyper and Van der Werf (2003, 2005).

Variables and instruments

Personality characteristics. We used the Dutch version of the Five-Factor Personality Inventory (FFPI) of Hendriks, Hofstee, and De Raad (1999a, 1999b). The questionnaire was administered by the schools in the 9th grade as part of a larger questionnaire on several topics (Kuyper & Van der Werf, 2005). It consisted of 100 items on a 5-point scale; 10 positively and 10 negatively formulated items represent each of the Big Five personality factors. The answer categories were: 1 = *not at all accurate*, 2 = *little accurate*, 3 = *moderately accurate*, 4 = *largely accurate*, 5 = *fully accurate*, and a final category ? = *don't know*. The FFPI is scored using a factor analytic scoring program yielding five *compatible anchored factor scores* (Hofstee & Hendriks, 1998). These are standardized scores anchored at the *midpoint* of each scale that are computed as weighted linear combinations of the student's responses to all items. Consequently, their means may differ from zero. The advantage of factor scores instead of simple sum scores is that the constructed Big Five factors are uncorrelated. The internal consistency reliabilities (stratified-alpha) of the five factors were: Extraversion (α = .84[1]), Agreeableness (α = .82), Conscientiousness (α = .84), Emotional Stability (α = .83), and Autonomy (α = .72). The factor scores were found to be factorially valid for this age group (Hendriks, Van der Werf, & Kuyper, *in preparation*), and met the predictive validity (e.g. for school success; Lubbers, Van der Werf, Kuyper, & Hendriks, 2010) and the discriminative validity criteria (e.g. between boys and girls; Hendriks et al., 2008).

Mathematical ability. The construct of math ability was based on three math-related tests. We calculated a combined math ability score for each student. Following recommendations of Kamata, Turhan, and Darandari (2003), stratified-alpha was used to estimate the reliability of this measure. In our sample, the estimated reliability was .92. More information about the tests and the procedure can be requested from the corresponding author.

Study profile. At the end of the 9th grade, students in track A and B chose one of the four study profiles: science & technology (SCIENCE), science & health (HEALTH), economics & society (ECONOMY), and culture & society (CULTURE). The students' choices were provided by Statistics Netherlands (CBS). Students who had chosen two profiles (mostly a combination of the two science profiles or the two society profiles) were recoded into the most science-oriented profile. This was the case for 1% of the students.

[1] The reported α-s are based on students who pursued track A. The α-s for students participating in track B are respectively .81 (Extraversion), .81 (Agreeableness), .82 (Conscientiousness), .81 (Emotional Stability), and .71 (Autonomy).

Analyses

Because the profiles systematically differed in science-orientation, we used Helmert contrasts in the analyses of (co)variance to test the differences among them. SCIENCE was the most science-oriented profile, HEALTH was less science-oriented, and ECONOMY and CULTURE were the least science-oriented (in this order[2]). In line with this ordering, three Helmert contrasts were used: Helmert 1 (SCIENCE versus HEALTH, ECONOMY, and CULTURE), Helmert 2 (HEALTH versus ECONOMY and CULTURE), and Helmert 3 (ECONOMY versus CULTURE). In all statistical tests we used an alpha level of .05.

Results

In our sample, the individual scores on the five personality factors ranged from -4.47 to 4.94. Table 1 shows the descriptive results of the personality scores. Figure 1 graphically presents the personality differences among the profiles.

Table 1 *Descriptive results of the students' personality scores (overall and per study profile)*

	SCIENCE	HEALTH	ECONOMY	CULTURE	Total
Means and standard deviations:					
Extraversion	0.69 (0.95)	1.07 (0.94)	1.24 (0.94)	1.36 (0.94)	1.17 (0.96)
Agreeableness	1.54 (0.94)	2.08 (1.01)	1.70 (1.06)	2.30 (1.01)	1.94 (1.06)
Conscientiousness	0.17 (1.16)	0.12 (1.15)	0.09 (1.11)	-0.02 (1.16)	0.07 (1.14)
Emotional Stability	1.47 (0.85)	1.13 (0.93)	1.20 (0.92)	0.77 (1.08)	1.09 (0.99)
Autonomy	0.71 (0.86)	0.79 (0.90)	0.75 (0.92)	0.90 (0.98)	0.80 (0.93)
Average sex-difference (boys minus girls):					
Extraversion	-0.09	-0.23	-0.27	-0.23	-0.34
Agreeableness	-0.71	-0.67	-0.76	-0.80	-0.83
Conscientiousness	-0.07	0.02	-0.04	-0.11	0.03
Emotional Stability	0.68	0.46	0.62	0.57	0.65
Autonomy	-0.38	0.12	-0.05	0.18	-0.04

In the upper part of Table 1, we observe several differences. The most notable result is that SCIENCE students have lower scores on Extraversion and Agreeableness and higher scores on Emotional Stability than the other students. Moreover, the relation between some personality characteristics and the orientation of the study profiles (from the least

[2] There is no formal difference in science-orientation between ECONOMY and CULTURE, although one might argue that for example commercial arithmetic (as part of economics in the ECONOMY profile) is to some extent science-oriented.

science-oriented to the most science-oriented) seems monotonic (see Figure 1). The scores on Extraversion increase monotonically from SCIENCE to CULTURE students, which also applies to the Conscientiousness scores (they decrease monotonically). The lower part of Table 1 shows that boys are less extraverted and agreeable than girls, whereas girls are less emotionally stable than boys. Effect sizes (Cohen's *d*) for the overall sex-differences (based on independent sample t-tests) are respectively -0.36 (Extraversion), -0.86 (Agreeableness), 0.02 (Conscientiousness), 0.70 (Emotional Stability), and -0.04 (Autonomy). Other personality differences between the groups are less consistent.

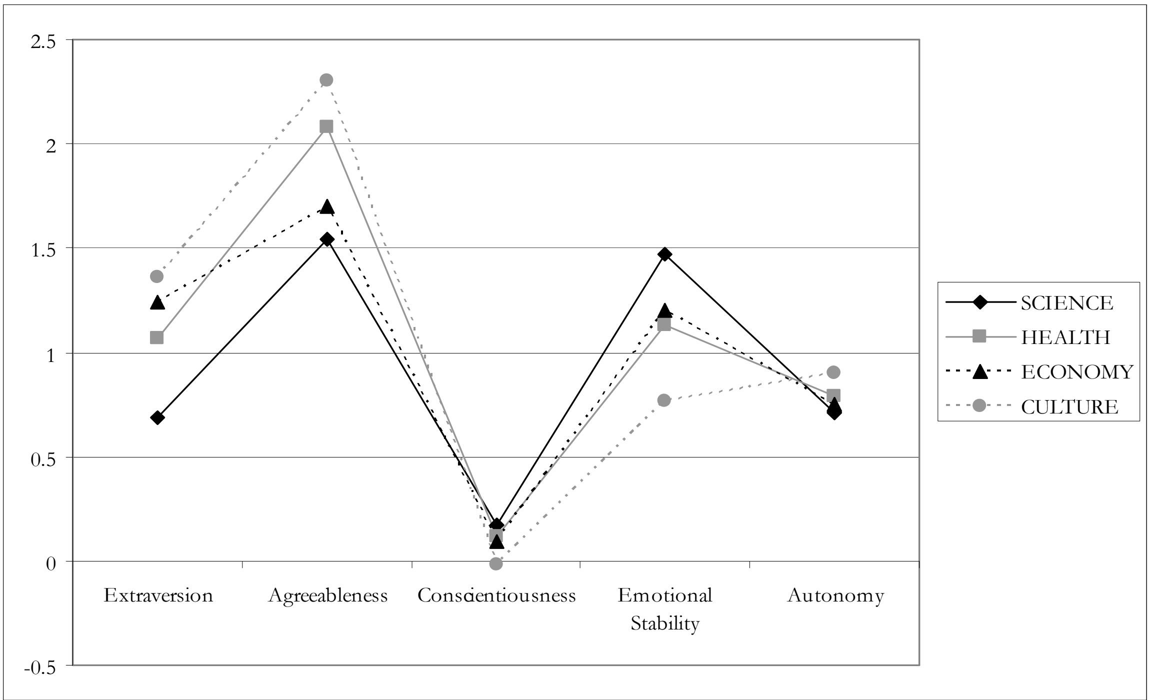

Figure 1 *Personality differences among the study profiles*

In our variance analyses of the five personality factors, we included profile, sex, and their interaction. Because of the large differences in mathematical ability among the students, this component was taken into account in the analyses in order to test the independent relationship between chosen study profile and students' scores on the personality factors. Therefore, we conducted a Profile x Sex ANCOVA for each personality factor with math ability as covariate (Table 2).

We observed significant differences among the profiles with respect to all five personality factors. Before elaborating on other significant effects in the analyses, we will first describe these differences, which were small (η^2; Cohen, 1988). For interpreting them (see the *Method* section), Helmert contrasts were used. Table 3 shows the contrast estimates.

Table 2 *Covariance analyses of the five personality factors*

	F^a	p-value	η^2
Extraversion (R^2 = .06)			
Mathematical ability	5.32	.02*	.00
Profile	18.30	.00**	.01
Sex	18.94	.00**	.01
Profile x Sex	0.37	.77	.00
Agreeableness (R^2 = .17)			
Mathematical ability	2.76	.10	.00
Profile	17.06	.00**	.01
Sex	228.55	.00**	.05
Profile x Sex	0.60	.62	.00
Conscientiousness (R^2 = .01)			
Mathematical ability	11.65	.00**	.00
Profile	5.84	.00**	.00
Sex	0.78	.38	.00
Profile x Sex	0.34	.80	.00
Emotional Stability (R^2 = .12)			
Mathematical ability	0.18	.68	.00
Profile	7.60	.00**	.01
Sex	156.14	.00**	.04
Profile x Sex	1.45	.23	.00
Autonomy (R^2 = .01)			
Mathematical ability	0.41	.52	.00
Profile	7.50	.00**	.01
Sex	0.42	.52	.00
Profile x Sex	5.45	.00**	.00

Notes. * p < .05, ** p < .001; [a] Degrees of freedom are (1, 3983) for Mathematical ability and Sex, and (3, 3983) for Profile and Profile x Sex, respectively.

Helmert 1 (see Table 3) indicates that SCIENCE students significantly differ in their scores on Extraversion from students who chose other study profiles. The accompanying confidence interval affirms that we can be quite certain about our conclusion (it does not include 0); SCIENCE students are more introverted than other students, independent of the relationship between math ability and Extraversion. They also have (on average) higher scores on Conscientiousness than the other students. In line with these results, Helmert 2 indicates that HEALTH students are also less extraverted than ECONOMY and CULTURE students. In addition, they have higher scores on Conscientiousness, Emotional Stability, and Agreeableness than ECONOMY and CULTURE students. The third contrast shows that ECONOMY students have higher scores on Emotional Stability and Conscientiousness than CULTURE students, whereas CULTURE students have higher scores on Agreeableness and Autonomy than ECONOMY students. We will discuss the interpretation of these differences in the discussion.

Table 3 *Contrast estimates of differences among the four study profiles*

			95% confidence interval	
		Contrast estimate	Lower	Upper
Helmert 1: SCIENCE versus HEALTH, ECONOMY, and CULTURE				
	Extraversion[a]	-0.43***	-0.59	-0.28
	Agreeableness	-0.11	-0.27	0.05
	Conscientiousness	0.20*	0.02	0.39
	Emotional Stability	0.08	-0.08	0.23
	Autonomy	0.02	-0.14	0.17
Helmert 2: HEALTH versus ECONOMY and CULTURE				
	Extraversion	-0.20***	-0.28	-0.12
	Agreeableness	0.09*	0.01	0.17
	Conscientiousness	0.15**	0.05	0.24
	Emotional Stability	0.12**	0.04	0.20
	Autonomy	-0.05	-0.13	0.02
Helmert 3: ECONOMY versus CULTURE				
	Extraversion	-0.01	-0.10	0.07
	Agreeableness	-0.28***	-0.37	-0.19
	Conscientiousness	0.17**	0.06	0.27
	Emotional Stability	0.19***	0.10	0.28
	Autonomy	-0.21***	-0.30	-0.12

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$; [a] One-tailed test.

In addition to these differences in personality characteristics, Table 2 shows that math ability was significantly related to Extraversion (the higher one's math ability, the lower one's score on Extraversion) and to Conscientiousness (the higher one's math ability, the higher one's score on Conscientiousness). These relationships are, however, not necessarily causal. Furthermore, in accordance with the literature we see several significant personality differences in gender. Boys have lower scores on Extraversion and Agreeableness than girls, whereas boys score higher on Emotional Stability. Finally, we find a significant interaction-effect between profile and sex on Autonomy. We also used Helmert contrasts to test the differences in the interaction-effects (factor-contrast-interaction). Parameter estimates (not presented here) show that SCIENCE boys have significantly lower scores on Autonomy than SCIENCE girls (contrast estimate -1.38, $p < .01$; 95% confidence interval [-2.29 to -0.47]). Similarly, ECONOMY boys show significantly lower scores on Autonomy than ECONOMY girls (contrast estimate -0.23, $p < .01$; 95% confidence interval [-0.41 to -0.06]). In contrast, in the baseline group (CULTURE students), girls have higher scores on Autonomy than boys. No sex-differences were observed as regards this factor between HEALTH boys and HEALTH girls (contrast estimate 0.12; 95% confidence interval [-0.19 to 0.43]).

Discussion

The primary goal of this study was to investigate the relationship between students' personality characteristics and their study profile choice in secondary education. We observed significant differences among the four profiles (SCIENCE, HEALTH, ECONOMY, and CULTURE) with respect to all five personality factors. In general, the more science-oriented profiles seemed to attract more introverted students, whereas the least science-oriented profiles drew more extraverted students. As expected, we found a negative association between Extraversion and the choice of advanced mathematics and science courses (i.e. the SCIENCE study profile), which remained significant when students' math ability was taken into account (see also Lapan et al., 1996)[3]. Presumably, the more extraverted students associated SCIENCE less with social activities and therefore chose a more society-oriented profile, such as CULTURE. In addition, the least science-oriented profiles attracted less conscientious and less emotionally stable students than the more science-oriented profiles. The more science-oriented the profile, the higher the score on the two factors. These results provide further empirical support for Holland's theory (1997), in particular in secondary education.

In addition, our results revealed differences in Agreeableness between students choosing ECONOMY and CULTURE. This finding is in line with Tokar, Vaux, and Swanson (1995) who report a relation between Agreeableness and social interests, albeit only for girls. A possible explanation for this finding is that students select school subjects which match their personality and prepare them for their desired professions (Holland, 1997). So the CULTURE profile prepares students for more socially-oriented professions whereas the ECONOMY profile is more focussed on business. However, this explanation would imply that students intuitively "feel" whether a discipline "fits their personality" and that they are fully informed about the career possibilities of these profiles, which seems unlikely. Maybe, they associate particular students (and teachers) with particular school subjects. Moreover, we found that the society profiles attracted less emotionally stable students than the more science-oriented profiles. We do not have a sound explanation for this result. A longitudinal investigation of the relationship between personality development and educational choices would be more suitable for addressing this issue. For example, we suggest research that investigates whether personality differences among students choosing different study profiles either increase or diminish throughout their educational careers. Do students' study profile choices strengthen their personality differences?

[3] Similar results were found in the subsample of "high math ability" students (as defined in Chapter 2). These additional results are presented in Appendix B of this dissertation.

Further, we noticed a significant interaction-effect between study profile and sex on Autonomy. Here, boys in SCIENCE and ECONOMY had lower scores on Autonomy than girls, whereas CULTURE girls had higher scores than CULTURE boys on this factor. Although the interaction-effect was small, it revealed that, presumably, SCIENCE girls intentionally deviated from the majority of the girls because they enjoyed mathematics or aspired to a science-oriented career (an autonomous choice). On the other hand, boys who deviated from the majority of the boys (i.e. did not choose ECONOMY) autonomously opted for a different profile.

Without further investigating the relationship between personality characteristics and educational choices, the results of our study are preliminary to practical implications. However, our results do suggest that schools could focus more on helping students choose a study profile that "fits them", that is, fits their personality. This is important because this choice significantly restricts their career possibilities. We recognise, however, that it is still unclear whether personality differences really play an important role in students' educational career, in particular because of the small effect sizes found.

In addition, there are a number of limitations to consider when interpreting and generalizing the present findings. The educational system in which students have to choose a study profile differs from those in most other countries. When generalizing our results to foreign student populations, this complication should be taken into account. Another limitation is that we measured personality by means of self-reports during adolescence, whereas one's personality is not yet fully developed at age 15 (Pullmann et al., 2006). However, since our 9th grade FFPI measures are sufficiently reliable and the students chose a study profile in this particular grade, we do not expect this to have largely influenced our results.

Despite these limitations, an important inference can be drawn from the present work. This paper demonstrates that personality differences exist among students who choose different sets of school subjects, which confirms the relationship between educational choice and personality in secondary education. Given the limitations of the present study, we suggest that future research includes personality in educational choice models. In this way, the relative importance of this component can be revealed in comparison to common factors, such as ability, background characteristics, and attitudes. This research should integrate the direct as well as the indirect effects of personality. For example, personality might influence students' choices indirectly through their educational aspiration (e.g. Gasser et al., 2004).

In sum, studying the effects of personality on the various aspects of student behaviour (e.g. subject choice) in secondary education is an important spearhead in both future research and in educational practice.

Chapter 5

Who Succeeds in Advanced Mathematics and Science Courses?*

Abstract

Few students (particularly few girls) currently choose to take their Final School Examination (FSE) in advanced mathematics, chemistry, and physics, a combination of subjects which is the best preparation for a science-oriented study in higher education. Are these subjects attainable by more students than is currently the case? This study examined 6,033 students in upper secondary education including 720 students who took their FSE in advanced mathematics, chemistry, and physics. The results show that the latter group (and in particular the girls in that group) had higher scores on math ability than students who chose other examination subjects. Regression analyses demonstrated the relative importance of math ability and achievement motivation for attainment in these science subjects. However, an expected positive effect of homework time as well as possible mediating and moderating effects of the predictors could not be confirmed.

* This chapter is based on: Korpershoek, H., Kuyper, H., van der Werf, M. P. C., & Bosker, R. J. (2010). Who succeeds in advanced mathematics and science courses? *British Educational Research Journal.*

Introduction

As a result of international agreements aimed at increasing students' intake in so-called STEM studies (science, technology, engineering, and math) in Europe (European Commission, 2002, 2004), the Dutch government attempts to attract students' interest in these studies (Ministry of Education, Culture and Science, 2004). The European secretaries of state aimed at a 15% increase of students graduating from tertiary STEM courses in the European Union (EU) between 2000 and 2010. In the Netherlands, students are already pre-sorted into different fields of study in secondary education. At the end of the 9th grade, students preparing for higher education choose one out of four possible combinations of school subjects (called "study profiles") in which they take their Final School Examination (FSE). A detailed description of the Dutch educational system and curriculum is given in *The present study* section of this paper. Taking the FSE in the combination of advanced mathematics, chemistry, and physics is mandatory for entering most science-oriented studies in higher education and offers numerous study possibilities in almost all higher professional or university disciplines. However, in spite of several campaigns to increase Dutch students' enrolment in advanced mathematics and science courses in secondary education, still only a few students (among which are particularly few girls) currently choose this combination of subjects (Statistics Netherlands, 2008; Van Langen, Rekers-Mombarg, & Dekkers, 2008). Common factors that have been put forth to explain students' subject choices, in particular their choice of mathematics (e.g. Eccles et al., 1985, Eccles, 1987, 2005; Van Langen, 2005), are: (1) ability (Jonsson, 1999; Roger & Duffield, 2000; Uerz, Dekkers, & Beguin, 2004), (2) background characteristics, such as sex, socioeconomic status, and ethnicity (Roger & Duffield, 2000; Uerz et al., 2004; Van Langen, 2005), (3) perceived difficulty of mathematics and expectations of success in mathematics (Crombie et al., 2005; Eccles et al., 1985; Jonsson, 1999; Muzzatti & Agnoli, 2007; Roger & Duffield, 2000; Stipek & Gralinski, 1991; Stokking, 2000; Woolnough, 1994), and (4) attitudes toward science-related domains (Dryler, 1999; Frost, Hyde, & Fennema, 1994; Li, 1999; Osborne, Simon, & Collins, 2003; Weinburgh, 1995). The present study focusses on the first explanatory factor (ability) to explain students' subject choices.

An additional topic of interest in the EU is the imbalance between men and women in STEM participation. Sells (1980) argues that mathematics serves as a "critical filter" when students (girls in particular) fail to take high school mathematics when it becomes optional. Girls' overall performance in school appears to be higher than boys' (e.g. Gorard, Rees, & Salisbury, 2001). Moreover, the Programme for International Student Assessment (PISA) 2006 study (Organisation for Economic Co-operation and Development [OECD], 2007) reveals that on average girls outperform boys in reading in all OECD countries, but that in many countries boys outperform girls in mathematics (see also Kuyper & Van der Werf, 2005; Mullis, Martin, & Foy, 2008). Since prior performance is the best predictor of students' subject choice (Van Langen, 2005), the connection between girls' average lower performance in mathematics and their subject choices in (Dutch) secondary education is evident.

Despite extensive research in this field, little is known about actual ability requirements necessary for a successful completion of mathematics, chemistry, and physics at the FSE. The national STEM education debate – and the international debate as well – focusses primarily on *how* we can attract students' interest in STEM studies, while the question *which* students should be attracted usually remains unanswered. Therefore, the present study tries to fill this gap by investigating the math ability of students who successfully completed their FSE in these subjects (hereafter called "science students"). Accordingly, the first purpose of this study is to compare the average math ability of science students with the average math ability of other students (i.e. students who took their FSE in for example biology, economics, and/or languages). This comparison reveals which students, as far as their math ability is concerned, would plausibly perform equally well as science students at the math/science exams had they chosen these subjects at the FSE. In other words, it reveals whether there are more students eligible for taking the FSE in advanced mathematics and science courses than currently take it and, subsequently, if more students are eligible for continuing in a STEM study at the higher educational level. In this comparison we make a distinction between boys and girls to examine whether girls "need" more math ability than boys to perform equally well at the math/science exams. Although assessing the eligibility based purely on math ability is debatable, we think that stimulating students with sufficient math ability (i.e. comparable to the math ability of successful science students) to choose this field of study is more profitable than large-scale campaigns that focus on students in general. We base this argument on Tempelaar, Gijselaers, Van der Loeff, and Nijhuis (2007) who stress that trying to convince students that hard subjects (e.g. statistics) are valuable is not effective. Their research shows that working on students' cognitive competence is a more promising approach to promote students' choice for hard subjects.

Once science students in the Netherlands enter the year of their examination, around 95% of the students pass the FSE and receive a diploma. Therefore, the second purpose of this study is to investigate to what extent science students' grade point average (GPA) on advanced mathematics, chemistry, and physics is influenced by their math ability. Because most students completed the FSE successfully, we are particularly interested in science students with relatively low math ability. What factors, other than math ability, contribute to their success at the FSE (e.g. Schreiber, 2002)? Obtaining sufficient grades clearly is influenced by other factors as well. For the present study, we limit ourselves to the effects of achievement motivation and homework time. Achievement motivation in particular has been found useful for the prediction of student achievement (Kuyper, Van der Werf, &

Lubbers, 2000; Murphy & Alexander, 2000). Although many researchers have investigated the relationship between homework time and student achievement, it is still ambiguous. Positive as well as negative relationships between homework time and student achievement have been observed in the past. Recently, however, Cooper, Robinson, and Patall's (2006) review reveals consistent evidence for a positive relationship between homework time and student achievement between 1987 and 2003. Therefore, we expect homework time to have a positive effect on student achievement in addition to the effects of ability and achievement motivation. We will elaborate on these relationships in the theoretical framework. We emphasize that including more (and perhaps more important) factors on the student level (e.g. socioeconomic background), the class/teacher level (e.g. the learning climate), and the school level (e.g. time tables) would increase the explanatory power of our model (see Reynolds & Teddlie [2000] for a review on school effectiveness research), but, instead, we chose to focus on a selection of three explanatory factors to study the relationship among them in more detail, in a particular group of students (i.e. science students) and in a particular achievement setting (i.e. students' GPA on advanced mathematics, chemistry, and physics). These analyses reveal which student characteristics, with respect to math ability, achievement motivation, and homework time, are "needed" for a successful completion of advanced mathematics and science courses at the FSE and, consequently, which students are eligible for STEM studies in higher education. We will elaborate on the effects of achievement motivation and homework time on student achievement in the next section. Subsequently, hypotheses are formulated based on these findings, as well as an extensive description of supplementary analyses to reveal the underlying relationships between math ability, achievement motivation, and homework time.

Theoretical framework

Achievement motivation and student achievement

Many definitions of achievement motivation are used in the field of educational research. A classic definition is the one of Atkinson and Reitman (1958), which refers to the tendency of a person to want to achieve. The underlying theory of achievement motivation states that achievement is the result of a conflict between two needs: striving for success and avoiding failure. Various scholars have used these constructs to measure students' achievement motivation in the educational context. Currently, other motivation theories have been introduced into the field, of which the achievement goal theory (e.g. Elliot & McGregor, 2001; Pintrich, 2000) and the self-determination theory (e.g. Deci & Ryan, 2000) receive the most attention. These approaches use different definitions of achievement motivation. Since a complete overview of these definitions is beyond the scope of this article (see, for example, Elliot, 2004; Martin & Dowson, 2009; Wigfield & Eccles, 2002), we have focussed on the relationship between motivation and student achievement, while paying special attention to the classic definition of achievement motivation.

Various studies have demonstrated that students' achievement motivation partly predicts student achievement (e.g. Edwards & Waters, 1981; Hirschfeld, Lawson, & Mossholder, 2004; Hustinx, Kuyper, & Van der Werf, 2005; Kuyper et al., 2000). For example, in a study by Hirschfeld et al. (2004) cognitive ability and achievement motivation together account for 27% of the variance in students' GPA, while an additional 2% is explained by the interaction between these two predictors. In addition, the studies of Hustinx et al. (2005) and Kuyper et al. (2000) show that achievement motivation is a prominent predictor of students' GPA next to the effect of prior achievement. Notwithstanding the positive effects of achievement motivation on student achievement, Gagné and St. Père (2001) question the crucial role of this predictor as a determinant of achievement. In their study, students' self-assessments of their motivation (intrinsic, extrinsic, and persistence) are not related to their GPA. Here, students' cognitive abilities are by far the best predictor of their GPA. Differences in the measure construct of achievement motivation might be due to this discrepancy.

Edwards and Waters (1981) also investigate the relationship between cognitive ability and students' GPA, concluding that achievement motivation moderates the relationship between these two variables. They explain that students with a high score on achievement motivation are probably more persistent in their efforts to perform at their maximum level of ability than students with a low score on achievement motivation. In line with these results, Hirschfeld et al. (2004) argue that cognitive ability is a stronger predictor of students' GPA at a higher than at a lower level of achievement motivation. In their discussion they elaborate on the interaction between ability and achievement motivation, arguing that achievement motivation and cognitive ability are more likely to combine multiplicatively than additively in predicting students' GPA. They explain this as follows: *"A multiplicative model implies that, in contrast to an additive model, high levels of trait motivation cannot compensate sufficiently for low levels of ability, and that high levels of ability cannot compensate sufficiently for low levels of trait motivation. That is, an interactive model suggests that both factors operate in tandem such that for highly motivated individuals, ability becomes even more important (rather than remaining constant in its degree of importance) as a predictor of performance. It also suggests that for individuals who possess high levels of ability, motivation becomes even more important as a predictor of performance."* (p. 2402). In contrast, several researchers have failed to provide empirical support for the interaction between cognitive ability and achievement motivation in predicting student achievement. Hirschfeld et al. (2004) point out that rather than using a context-specific (e.g. academic) measure of achievement motivation, three of these studies (Mount, Barrick, &

Strauss, 1999; Sackett, Gruys, & Ellingson, 1998; Wright, Kacmar, McMahan, & Deleeuw, 1995) apply a more general one, for instance conscientiousness. Therefore, in their own study Hirschfeld et al. (2004) divide achievement motivation into general achievement motivation and context-specific achievement motivation. As stated above, their study shows that context-specific achievement motivation (e.g. academic) is a moderator of the relationship between cognitive ability and students' GPA. It does not confirm, however, a moderating effect of general achievement motivation.

Additionally, some studies focus on the relationship between achievement motivation and mathematics achievement rather than on student achievement in general, with various results. Reynolds and Walberg (1992), Singh, Granville, and Dika (2002), and Shores and Shannon (2007) report a significant contribution of motivation to mathematics achievement, independent of prior achievement. In contrast, Schiefele and Csikszentmihalyi (1995) cannot confirm an effect of achievement motivation on mathematics achievement when ability is taken into account. As with student achievement in general, ability proves to be the best predictor of mathematics achievement. Schiefele and Csikszentmihalyi point out that the impact of affective variables is often underestimated because they tend to have indirect rather than direct effects on student achievement. For example, Meece, Wigfield, and Eccles (1990) only observe an indirect effect of math anxiety on students' mathematics achievement, resulting from the perception of their math ability. In line with these results, Reynolds and Walberg (1991) argue that motivation in the form of out-of-school reading and engagement in schoolwork influences science achievement only indirectly.

In sum, this overview reveals we can expect a positive relationship between achievement motivation and student achievement.

Homework time and student achievement

The majority of studies using homework behaviour as a predictor for student achievement focus on the time that students spend on their homework. In recent years, several researchers have published meta-analyses of the relationship between multiple aspects of effort (among which is time spent on homework) and student achievement (e.g. Cooper et al., 2006; Cooper & Valentine, 2001; Trautwein, 2007; Wagner, Schober, & Spiel, 2008). For example, based on an investigation of 32 studies published between 1987 and 2004, Cooper et al. (2006) provide consistent evidence for a positive relationship between homework and student achievement. These authors conclude that most studies report a minor positive relationship between homework time and student achievement. They report an average correlation of .24 with standardised test scores and an average correlation of .27 with students' GPA. Earlier research (e.g. Cooper, 1989; Hustinx et al., 2005; Kuyper & Swint, 1996; Singh, Granville, & Dika, 2002) shows similar results. The relationship between homework time and student achievement appears to be stronger for students in higher grade levels (Cooper et al., 2006; Cooper & Valentine, 2001). Cooper, Lindsay, Nye, and Greathouse (1998) observe no significant relationship between homework time and standardised test scores (see also Trautwein, 2007). However, when using the students' GPA as a measure of student achievement, they discern a weak positive relationship. Also Cooper et al. (2006) acknowledge that the relationship between homework time and student achievement is stronger when students' GPA is used instead of standardised test scores.

Some studies report a non-linear relationship between homework time and student achievement. With respect to high school students, Cooper's (1989) meta-analysis shows a positive and linear relationship between homework time and student achievement (students' GPA as well as standardised test scores), at least for the students who spend more than one hour per week on their homework and no more than two hours per day (the highest measured interval). However, for students who spend less than one hour per week on their homework, no positive relationship is found. Moreover, Lam (1996) observes non-linear effects of homework on achievement across all amounts of homework. Cooper (1989) suggests that too much time spent on homework may be less effective or even counterproductive and that, alternatively, with respect to low ability students, extra time spent on homework cannot compensate for their lower level of ability. Additionally, De Klerk, Simons, and Zuylen (1989) introduce the concept of the *compensation-effect*. This effect occurs when students with lower cognitive abilities spend more time on their homework and achieve the same school results as students with higher cognitive abilities who spend less time on their homework. In other words, students compensate for their lower ability by spending more time on their homework.

Based on these findings, we expect a small positive relationship between homework time and student achievement when measured with students' GPA.

The present study

From the literature review we can conclude that cognitive ability, achievement motivation, and homework time are predictors of student achievement (i.e. students' GPA). Although some studies pay special attention to achievement in mathematics, none of them focusses on the concept of combined student achievement in advanced mathematics, chemistry, and physics, which is mandatory for entering a science-oriented study (STEM) in (Dutch) higher education. The present study aims at extending the current knowledge about this topic by replicating previous findings in this particular context and clarifying the relations among math ability, achievement motivation, and homework time in predicting science students' examination grades in advanced mathematics, chemistry, and physics. Before we describe the present study further, we will first elaborate on the mandatory combination of subjects in the Dutch educational system, because it is essential for understanding the context in which we conducted our study. In the Netherlands, students enter secondary education (7th grade) at age 12 or 13. Based on their previous achievement and the primary school teacher's advice students enter one of the three basic tracks in secondary education: preparatory secondary vocational education (track C), senior general secondary education (track B), or pre-university education (track A). The first track (the lowest track, duration four years) prepares students for senior secondary vocational education, which at most belongs to level 4 (post-secondary non-tertiary education) of the 1997 International Standard Classification of Education (ISCED97). The two latter tracks prepare students for tertiary education; senior general secondary education (the middle track, duration five years) prepares students for higher professional education and pre-university education (the highest track, duration six years) prepares students for university. Both forms of higher education belong to level 5a of ISCED97. At the end of the 9th grade, students in these latter two tracks choose one out of four possible combinations of school subjects, called "study profiles". Next to science & technology (SCIENCE), students can choose science & health (HEALTH), economics & society (ECONOMY), or culture & society (CULTURE), or a combination of two profiles. Besides subjects that are common in all profiles (e.g. Dutch and English language), SCIENCE and HEALTH students take their Final School Examination (FSE) in advanced mathematics, chemistry, and physics; less time is spent on these subjects in the HEALTH profile, as the content of this profile is more elementary and less science-oriented. The HEALTH profile also includes biology. The ECONOMY and CULTURE profiles roughly consist of applied mathematics (both), history (both), economics (ECONOMY), and modern languages (CULTURE). Formally, the study profile choice is unrestricted and is based on students' interests and ambitions. However, the student's decision usually takes place in interaction with his/her parents, teachers, and school counsellors and can therefore be restricted to some extent.

As stated in the introduction, the present study consists of two parts. First, we explored (sex-)differences in math ability between students who took their FSE in advanced mathematics, chemistry, and physics ("science students") and students who took their FSE in other subjects. We expected that science students would score higher on math ability than students of the latter group (e.g. Van Langen & Vierke, 2006) and that boys would have higher scores on math ability than girls (e.g. Mullis et al., 2008). Besides replicating previous findings, we elaborated on sex-differences by testing the following hypothesis: we expected that girls taking their FSE in advanced mathematics, chemistry, and physics would score higher on math ability than boys taking their FSE in these subjects, whereas girls choosing other subjects for their FSE would have lower scores on math ability than boys in this category (Hypothesis 1). This hypothesis is based on the assumption of (self-)selection processes; because girls in general perceive advanced mathematics and science courses as too difficult for them (e.g. Stokking, 2000), we expect only high achieving girls to choose these subjects, whereas for boys, choosing these subjects is considered "normal".

The second part of the research concerned the importance of math ability, achievement motivation, and homework time on science students' GPA on advanced mathematics, chemistry, and physics and the relationship among these variables. We expected a positive relationship between students' math ability and their final examination grades on advanced mathematics, chemistry, and physics (Hypothesis 2). Additionally, we expected that students' examination grades in these subjects were also directly predicted by achievement motivation (Hypothesis 3) (e.g. Singh, Granville, & Dika, 2002) and by homework time (Hypothesis 4) (e.g. Cooper et al., 2006) after controlling for the effect of math ability. In supplementary analyses, we explored the mediating and moderating effects of these variables on students' examination grades in advanced mathematics, chemistry, and physics. Firstly, we examined whether homework time mediated the effect of achievement motivation on students' examination grades (i.e. whether through homework time achievement motivation had an indirect effect on top of the direct effect). Students who are highly motivated might spend more time on their homework than students who are less motivated (e.g. Reynolds & Walberg, 1991). Secondly, we tested whether a *compensation-effect* occurred (i.e. students compensating for their lower ability by spending more time on their homework [De Klerk et al., 1989]), by exploring the interaction between math ability and homework time. Thirdly, we tested whether achievement motivation moderated the relationship between math ability and students' examination grades (e.g. Hirschfeld et al., 2004) by investigating the interaction between math ability and achievement motivation. Finally, we explored the three-way interaction among math ability, homework time, and achievement motivation to look for a possible interaction between achievement motivation and homework time, which differed across the various levels of math ability.

Methods

Study design

The data used in this study were collected as part of a large-scale longitudinal study in The Netherlands, the "Cohort Studies in Secondary Education" (VOCL'99). In that study, students are being followed in their educational career from the 7th grade (age 12) onwards until they have completed their full-time education. The sample is considered representative of schools and students in Dutch secondary education. Various tests were administered in the first three cohort years to assess students' intelligence and achievement in for instance Dutch language and mathematics. In addition, extensive questionnaires were administered throughout the study, addressing topics such as students' motivation, learning styles, and aspirations. For more information on the VOCL'99 study we refer to Korpershoek, Kuyper, and Van der Werf (2006) and Kuyper and Van der Werf (2003, 2005).

Participants

The initial sample consisted of 6,033 students in tracks A and B for whom a measure of math ability was available (83% of the overall VOCL'99 sample of 7,252 students in these two tracks). For the other students in these tracks (the non-response group of 17%), a measure of math ability was lacking due to non-participation of schools and/or drop out of individual students. That is, some schools did not administer all requested tests (e.g. mathematics tests) or prematurely ended their participation in the cohort study. To a lesser extent, students who repeated a grade, refused to participate, or had dropped out of school were excluded from the data collection. Table 1 shows how many boys and girls were included in the present study and which study profiles (as previously described) they had chosen.

Table 1 *Study profile choices*

	Track A				Track B			
	N	% total	% boys	% girls	*N*	% total	% boys	% girls
SCIENCE	370	14.7	28.8	3.1	350	9.9	20.6	1.0
HEALTH	734	29.3	23.8	33.8	504	14.3	13.8	14.7
ECONOMY	844	33.6	39.8	28.5	1,379	39.1	51.7	28.6
CULTURE	561	22.4	7.6	34.6	1,291	36.6	13.9	55.6
Total	2,509	100.0	100.0	100.0	3,524	100.0	100.0	100.0

Information concerning students' background characteristics (sex, socioeconomic status, and ethnicity) and students' study profile choice is available for nearly all students of the overall VOCL'99 sample. In comparison to the overall VOCL'99 sample, our sample is considered representative of students' study profile choices, their sex, and their socioeconomic status (i.e. parental level of education), although we did find some small differences. The non-response in track B was larger for boys (18%) than for girls (16%) and in track A it was 16% for both boys and girls. We found a larger difference with respect to ethnicity; native Dutch students were over-represented in the response group. Non-response was 14% for native Dutch students in track A and 15% in track B, while it was 26% for students from ethnic minority groups in both tracks. However, as the sample size is large, we do not expect that these differences substantially affect the validity of the research results.

In the second part of this study SCIENCE students were studied in more detail, which originally consisted of 720 students. We chose SCIENCE students because passing the

FSE in a science-oriented study profile is mandatory to enter most science-oriented studies in Dutch higher education. For most other disciplines, a certificate in upper secondary education with no additional requirements is sufficient for admission. Although the HEALTH profile includes science subjects as well, the SCIENCE profile gives a better preparation for "hard" science studies and provides access to more science studies than HEALTH. We selected students of which additional information was available (i.e. a measure of math ability, examination grades, achievement motivation, and homework time, see next section) which resulted in a sample of 269 students (37%; 172 students in track A and 97 students in track B). The low response rate is largely due to non-participation of schools to administer another student questionnaire in the 11th grade, since they already administered several questionnaires and tests in the preceding school years. In addition, student dropout and individual non-response also contributed to this low response rate. The sample is considered representative with respect to SCIENCE students' socioeconomic status and ethnicity as compared to the overall SCIENCE sample. However, we found small differences with respect to students' sex and students' math ability (see next section) and performance at the FSE. In track A, girls were over-represented as compared to the overall SCIENCE sample in that track (19 versus 11% of the SCIENCE students) and the somewhat higher performing students were over-represented. On average, track A students in the response group scored 0.3 standard deviation (effect size Cohen's *d*) higher on math ability than track A students in the non-response group. These differences were not found for track B students. In both tracks, however, the students included in the subsample had a somewhat higher average examination grade (at the FSE) on advanced mathematics, chemistry, and physics than students excluded from the sub-sample (effect size 0.2 for track A and 0.3 for track B).

Variables and instruments

Mathematical ability. The construction of math ability was based on three math-related tests, which in essence represent a combination of nature (ability) and nurture (achievement). This measure enables one to compare the math ability of students with a large degree of certainty regarding their actual mathematics potential. The first test used was an arithmetic test administered in the 7th grade, developed by the Dutch National Institute for Educational Testing (Cito). The reliability (α) of the test was .83. Second, an intelligence test was used (the *Groninger Intelligentietest voor Voortgezet Onderwijs* [the Groningen Intelligence Test for Secondary Education], Van Dijk & Tellegen, 1994). The test was administered in the 8th grade and assessed as reliable and valid (Evers, Van Vliet-Mulder & Groot, 2000). The test consisted of a verbal and a symbolic intelligence part of which the results on the latter part were used to measure math ability (α for the symbolic intelligence part was .93). Third, a mathematics test for the 9th grade was used (also developed by Cito), of which the reliability (α) was .78. We calculated a combined math ability score for students who had completed at least two of these three tests. The range of this (standardised) score ran from -3.55 up to 4.44. Following recommendations of Kamata, Turhan, and Darandari (2003), stratified-alpha (as proposed by Cronbach, Shönemann, & McKie, 1965) was used to estimate the reliability of our math ability measure; this is intended for cases where components of a test can be grouped into subtests on the basis of content. In our sample, the estimated reliability was .92. More information about how this combined score was calculated can be requested from the corresponding author.

Academic achievement motivation. In the 11th grade, students filled in questionnaires that addressed several topics, among which achievement motivation. We used the classic construct of achievement motivation based on Atkinson and Reitman's (1958) definition (the tendency of a person to want to achieve), which we refer to as academic achievement motivation (hereafter called AAM) because of the scholastic context of the present study. We used a set of 16 items derived from the PMT-K (the *Prestatie-Motivatie Test voor Kinderen* [Performance Motivation Test for Children], Hermans, 1970, 1983). These items were combined into a reliable scale (α = .82) with scores ranging from 1 to 4.

Homework time. The 11th grade questionnaire also measured homework time. Students were asked to fill in how much time (on average) they spent on homework per day. The response categories ranged from (1) no homework, to (12) more than three hours, with increments of 15 minutes (Korpershoek et al., 2006).

Examination grades. At the end of the 11th (track B) or 12th (track A) grade, students take part in the Final School Examination. These national examinations are constructed by specialists at the Dutch Central Institute for Test Development (Cito). For each subject in which students take their FSE, students receive a grade between 1 (lowest grade) and 10 (highest grade) (a 6 is a pass). To pass the FSE, students must pass all subjects or can, in some specific cases, compensate low grades (a 4 or a 5) with high grades (> 7) for other subjects. The final examination grades of students in the VOCL'99 cohort were retrieved from Statistics Netherlands (CBS). For SCIENCE students, an average score on the science subjects was computed based on their examination grades on advanced mathematics, chemistry, and physics (hereafter called $GPA_{science}$).

Study profiles. As previously explained, students have to choose one of the four study profiles possible: science & technology (SCIENCE), science & health (HEALTH), economics & society (ECONOMY), or culture & society (CULTURE), or a combination of two profiles. We use Helmert contrasts in the analyses to test the differences among the four profiles, because the profiles can be arranged on an ordinal science-orientation scale: SCIENCE is the most science-oriented profile, HEALTH is less science-oriented, and the ECONOMY and CULTURE profiles are the least science-oriented. Consistent with this ordering of profiles, we expected that students' math ability is related to the study profile they choose (i.e. the higher their math ability, the more science-oriented the chosen study profile). Students who chose two profiles (mostly a combination of the two science profiles or the two society profiles) are recoded into the most science-oriented profile. Using Helmert contrasts, we can first compare SCIENCE students with all other students (HEALTH, ECONOMY, and CULTURE) (Helmert 1) and examine to what extent SCIENCE students deviate from the rest of the students with regard to their math ability. Since HEALTH students also pursue mathematics and science courses (although the profile is less science-oriented than the SCIENCE profile), the second Helmert contrast (Helmert 2) compares these students with students pursuing the least science-oriented profiles (ECONOMY and CULTURE). Finally, ECONOMY students are compared with CULTURE students in the third Helmert contrast (Helmert 3)[1].

Results

Differences in mathematical ability

Table 2 shows the average score on math ability in both tracks for all 6,033 students included in the study, per profile (SCIENCE, HEALTH, ECONOMY, and CULTURE), separately for boys and girls.

Table 2 *Average score on mathematical ability (standard deviations in parentheses)*

	Track A			Track B			Total
	Boys	Girls	Total	Boys	Girls	Total	
SCIENCE	1.07	1.23	1.09	0.22	0.52	0.24	0.68
	(0.87)	(0.79)	(0.87)	(0.81)	(1.02)	(0.82)	(0.94)
HEALTH	0.72	0.63	0.67	-0.13	-0.14	-0.13	0.34
	(0.84)	(0.86)	(0.85)	(0.78)	(0.93)	(0.87)	(0.94)
ECONOMY	0.52	0.29	0.42	-0.25	-0.40	-0.31	-0.04
	(0.85)	(0.79)	(0.83)	(0.85)	(0.88)	(0.87)	(0.92)
CULTURE	0.26	0.02	0.05	-0.55	-0.69	-0.66	-0.45
	(0.92)	(0.84)	(0.85)	(0.82)	(0.86)	(0.85)	(0.91)
Total	0.71	0.34	0.51	-0.18	-0.51	-0.36	0.00
	(0.90)	(0.88)	(0.91)	(0.86)	(0.90)	(0.90)	(1.00)

With SCIENCE students on top, differences in math ability among the students across the four profiles are evident. Table 3 shows the results of the analysis of variance.

[1] There is no formal difference in science-orientation between ECONOMY and CULTURE, although one might argue that for example commercial arithmetic (as part of economics in the ECONOMY profile) is to some extent science-oriented.

Table 3 *Analysis of variance for mathematical ability (N = 6,033)*

	F	*df*	*p*-value	Partial eta-squared
Track	433.50	1, 6017	.00**	.07
Sex	1.77	1, 6017	.18	.00
Profile	103.41	3, 6017	.00**	.05
Track x Sex	1.78	1, 6017	.18	.00
Track x Profile	0.45	3, 6017	.72	.00
Sex x Profile	4.97	3, 6017	.00*	.00
Track x Sex x Profile	0.03	3, 6017	.99	.00

Note. * $p < .01$, ** $p < .001$.

The model explains 28% of the variance in math ability, leaving much variance unexplained. This means that there is a large overlap in the distribution of math ability among the study profiles, implying that several students with a high math ability score did not pursue SCIENCE and, moreover, that some SCIENCE students did not have a high math ability score. There was a significant main effect of track on the students' math ability (track A students had higher scores on math ability than track B students), a significant main effect of profile, and a significant interaction between sex and profile. The main effect of track is of course not unexpected, because track A prepares students for a higher level in tertiary education than track B and therefore attracts, in general, higher performing students. Helmert contrasts were used to test the differences in math ability among the four profiles. Table 4 presents the contrast estimates.

Table 4 *Contrast estimates (Helmert)*

		95% confidence interval	
	Contrast estimate	Lower	Upper
Helmert 1: SCIENCE versus HEALTH, ECONOMY, and CULTURE	0.74*	0.62	0.86
Helmert 2: HEALTH versus ECONOMY and CULTURE	0.37*	0.31	0.43
Helmert 3: ECONOMY versus CULTURE	0.28*	0.21	0.35

Note. * $p < .001$.

The first Helmert contrast shows that the math ability of SCIENCE students is significantly higher than the math ability of students who pursue the other three profiles. The accompanying confidence interval affirms that we can be quite confident in our conclusion (it does not include 0); SCIENCE students have higher scores on math ability than students pursuing other profiles. The effect size for this difference (Cohen's *d*) is 0.8 for both tracks, in other words SCIENCE students on average scored 0.8 standard deviation higher than the other students. On the total range of our standardized math ability scale (which runs from -3.55 to 4.44) this is about 12% higher (on a test of 100 items this effect would mean an additional 12 items answered correctly). In addition, Helmert contrasts 2 and 3 show that the math ability of students rises on an ordinal scale from CULTURE (lowest average math ability) via ECONOMY and HEALTH to SCIENCE (highest average math ability). We will return to this point in the discussion.

Figure 1 shows the interaction between sex and profile as regards math ability. It confirms Hypothesis 1 that SCIENCE girls have higher scores on math ability than SCIENCE boys and that girls who pursue other profiles have lower scores on math ability than boys in this category (except for sex-differences within the HEALTH profile in track B).

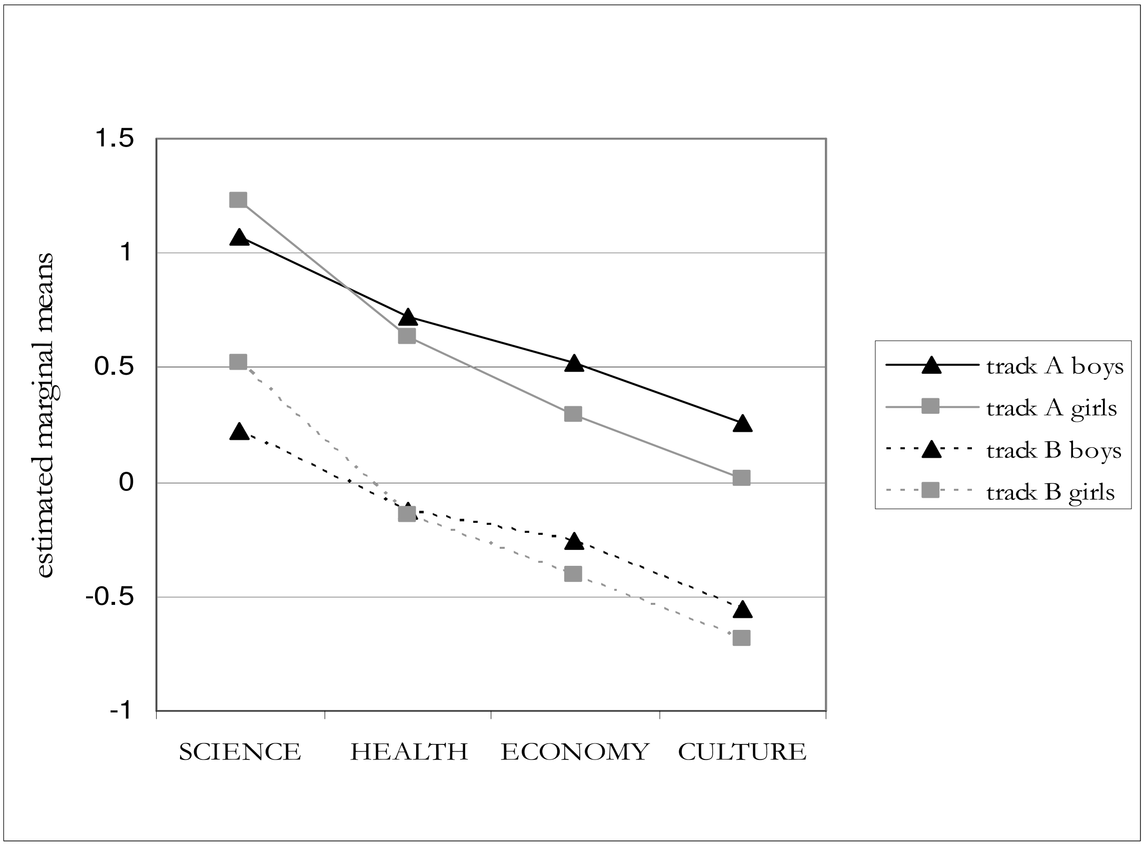

Figure 1 *Interaction sex and profile for math ability in track A (solid lines) and track B (dotted lines)*

Prediction of $GPA_{science}$

Within the group of SCIENCE students, correlations were calculated between math ability, AAM, homework time, sex, and $GPA_{science}$. Table 5 presents the results for track A and track B separately.

Table 5 *Correlations for SCIENCE students in track A (N = 172) and track B (N = 97)*

	Track A				Track B			
	Math.	AAM[a]	HWT[b]	Sex[c]	Math.	AAM[a]	HWT[b]	Sex[c]
Math ability								
AAM[a]	.05				-.14			
HWT[b]	-.10	.34***			-.23*	.31**		
Sex[c]	.02	.20**	.13		.11	.06	.16	
$GPA_{science}$[d]	.24**	.24**	-.07	-.08	.18	.21*	-.02	.04

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$; [a] AAM = academic achievement motivation; [b] HWT = homework time; [c] Point-biserial correlation: girls = 0; boys = 1; [d] $GPA_{science}$ = average examination grade on advanced mathematics, chemistry, and physics.

Table 5 shows significant positive correlations in both tracks between AAM and homework time, as well as between AAM and $GPA_{science}$. That is, a higher score on motivation corresponds with a higher score on homework time as well as a higher average grade on advanced mathematics, chemistry, and physics. In addition, in track A we found significant positive correlations between AAM and sex and between math ability and $GPA_{science}$. In track B we observed a significant negative correlation between math ability and homework time. The other correlations were not significant.

Multiple linear regression analyses were performed with $GPA_{science}$ as criterion variable. Sex was not included as predictor, because the correlation between sex and $GPA_{science}$ was very low and therefore not significant. We used stepwise regression, entering math ability in the first model, AAM in the second model, homework time in the third model, and the interaction terms in the fourth model. For track A, the first model with math ability as only predictor explained 6% of the variance in $GPA_{science}$. When AAM was added, the explained variance of the model increased to 11% and an additional 2% explained variance was found when homework time was added to the third model. Table 6 presents the Models 2, 3, and 4 for track A.

The results for Model 2 show significant positive effects of math ability and AAM on students' $GPA_{science}$, which confirms Hypotheses 2 and 3. Unexpectedly, in Model 3 the effect of homework time was negative, which is why we had to reject Hypothesis 4. Interestingly, when homework time was added in Model 3, AAM had a stronger relationship with $GPA_{science}$ than before controlling for this predictor (although the confidence intervals for AAM largely overlap in Models 2 and 3), while the explained variance increased by 2% even though the zero-order correlation between homework time and $GPA_{science}$ was only -.07. This effect is referred to as the *suppression effect*, whereby a suppressor forms a third variable which increases the regression coefficient between the independent and the dependent variable by its inclusion in a regression equation (Conger, 1974). In other words, the relationship between AAM and $GPA_{science}$ was (partly) hidden or suppressed by the suppressor "homework time".

Table 6 *Multiple regression analyses for average examination grade on advanced mathematics, chemistry, and physics in track A (only science & technology students; N = 172)*

			95% confidence interval for *B*	
	B (SE)	*β*	Lower	Upper
Model 2 (R^2 = .11)				
Constant	47.22 (5.82)		35.72	58.71
Mathematical ability[a]	3.38 (1.06)	0.23***	1.29	5.47
Academic achievement motivation (AAM)[a]	7.02 (2.23)	0.23***	2.63	11.42
Model 3 (R^2 = .13)				
Constant	46.00 (5.81)		34.52	57.48
Mathematical ability[a]	3.13 (1.06)	0.21**	1.04	5.22
Academic achievement motivation (AAM)[a]	8.57 (2.35)	0.28***	3.92	13.22
Homework time[a]	-0.62 (0.32)	-0.15*	-1.26	0.02
Model 4 (R^2 = .14)				
Constant	37.68 (11.99)		14.01	61.34
Mathematical ability[a]	8.01 (7.84)	0.55	-7.46	23.49
AAM[a]	11.17 (5.23)	0.36*	0.84	21.50
Homework time[a]	-0.19 (0.59)	-0.05	-1.35	0.97
Mathematical ability x AAM	-1.33 (3.41)	-0.24	-8.06	5.39
Mathematical ability x Homework time	0.01 (1.56)	0.00	-3.07	3.08
Mathematical ability x Homework time x AAM	-0.15 (0.55)	-0.18	-1.24	0.95

Notes. * p < .05, ** p < .01, *** p < .001; [a] One-tailed test.

To reveal the underlying pattern, the homework time variable was split into *below average* and *above average* time spent on homework. The correlation analysis showed that among students who spent little time on their homework (below average), the correlation between AAM and $GPA_{science}$ was .30, and among students who spent a lot of time on their homework (above average), it was .20. Thus, AAM was stronger related to $GPA_{science}$ for students who spent little time on their homework than for students who spent a lot of time on their homework.

Model 4 did not show any significant interaction effects; no evidence was found for a compensation-effect (students who compensate for their lower ability by spending more time on their homework), nor for a moderating effect of AAM on the relationship between math ability and students' $GPA_{science}$ or an interaction between achievement motivation and homework time, which differed across the various levels of math ability.

Table 7 presents the models for track B. The first model explains 3% of the variance in $GPA_{science}$, while AAM added 6% in the second model. Adding homework time (Model 3) did not increase the explained variance.

Table 7 *Multiple regression analyses for average examination grade on advanced mathematics, chemistry, and physics in track B (only science & technology students; N = 97)*

			95% confidence interval for *B*	
	B (SE)	β	Lower	Upper
Model 2 (R^2 = .09)				
Constant	55.58 (4.76)		46.14	65.02
Mathematical ability[a]	2.23 (1.04)	0.21*	0.15	4.30
Academic achievement motivation (AAM)[a]	4.52 (1.88)	0.24**	0.79	8.25
Model 3 (R^2 = .09)				
Constant	55.50 (4.78)		46.02	64.99
Mathematical ability[a]	2.12 (1.07)	0.20*	-0.01	4.25
Academic achievement motivation (AAM)[a]	4.81 (1.97)	0.25**	0.90	8.73
Homework time[a]	-0.18 (0.34)	-0.05	-0.86	0.51
Model 4 (R^2 = .13)				
Constant	58.90 (5.48)		48.02	69.79
Mathematical ability[a]	-8.81 (8.42)	-0.84	-25.53	7.91
AAM[a]	3.37 (2.22)	0.18	-1.04	7.78
Homework time[a]	-0.17 (0.35)	-0.05	-0.86	0.53
Mathematical ability x AAM	5.27 (3.35)	1.33	-1.39	11.93
Mathematical ability x Homework time	1.96 (3.11)	0.83	-4.22	8.15
Mathematical ability x Homework time x AAM	-1.01 (1.16)	-1.17	3.30	1.29

Notes. * p < .05, ** p < .01, *** p < .001; [a] One-tailed test.

We found significant positive effects of math ability and AAM on students' $GPA_{science}$ for track B, which confirms Hypotheses 2 and 3. As was the case for track A, the effect of homework time had a negative sign, but for track B the effect was not significant (we again reject Hypothesis 4). In addition, the regression coefficient of AAM increased slightly when homework time was added in Model 3, which confirms the possibility of a suppression effect of homework time (i.e. the relationship between AAM and $GPA_{science}$ is suppressed by homework time; see track A). Similar to the results of track A, the interaction effects were not significant.

Discussion

In line with the (inter)national agreements aimed at increasing students' participation in STEM studies, the present study had two primary purposes. The first was to investigate differences in math ability between students who took their FSE in advanced mathematics, chemistry, and physics (i.e. students who pursued the SCIENCE profile) and students who took their FSE in other subjects (i.e. students who pursued other profiles), to reveal if more students are eligible for taking the FSE in advanced mathematics and science courses than currently is the case. We also searched for sex-differences in math ability, since in particular few girls pursue these courses. The second objective was to examine the relative importance of math ability, AAM, and homework time in explaining differences in SCIENCE students' $GPA_{science}$ to reveal which "requirements" are necessary for a successful completion of mathematics, chemistry, and physics at the FSE.

Our results show significant differences in math ability among students in different tracks as well as between students who followed SCIENCE and those who had chosen other profiles. Next to the obvious difference in math ability between track A and track B (i.e. track A attracts higher performing students than track B), SCIENCE students had the highest average score on math ability, followed by HEALTH students, ECONOMY students, and CULTURE students, who had the lowest average score on math ability. This result implies that the mandatory study profiles not only distribute students across disciplines, but also distribute students with respect to their math ability to a certain degree. Given the fact that track, sex, and profile accounted for 28% of the variation in math ability, this result indicates that there is a large overlap in the math ability distribution among the profiles. Apparently, several students with a high math ability score did not pursue SCIENCE but could have pursued this profile based on their math ability score. That is, regarding students' math ability, more students could have chosen SCIENCE (and eventually a STEM study in higher education) than currently is the case. This result strengthens the argument that although the system of study profiles prepares students adequately for different fields of study in higher education, the early pre-sorting in secondary education of students in four main disciplines might have a negative effect on students' entry in STEM studies (see also Van Langen et al., 2008). Unfortunately, the effect of the mandatory study profile choice in the Netherlands on students' entry in STEM studies in higher education can not be answered based on the available data. The system of pre-sorting students is not typically Dutch; therefore we suggest that it would be valuable to compare the educational systems across several countries with regard to this issue. Since taking mathematics and science subjects in secondary education is the most direct preparatory route for a science-oriented study in higher education, students' subject choice in secondary education is the first moment in the system where sufficiently talented students leave the STEM-pipeline (Van Langen & Dekkers, 2005).

On the other hand, some SCIENCE students did not have a high math ability score but successfully completed the SCIENCE profile, demonstrating that many other factors influenced students' study profile choices as well. We found a significant interaction-effect between study profile and sex on students' math ability. Girls who pursued SCIENCE scored higher on math ability than SCIENCE boys, whereas girls who followed other profiles had lower scores on math ability than boys who pursued other profiles. This result confirms Hypothesis 1, and illustrates that only the highest achieving girls pursued SCIENCE. Presumably, these girls have a higher ability self-concept in mathematics, which influenced not only their subject choices (e.g. Eccles, 2005) but also their academic achievement (Marsh, 1990; Steinmayr & Spinath, 2008). An investigation of the performance of SCIENCE girls in STEM studies and their persistence in STEM careers may reveal the necessity of this average higher ability level. It would be helpful to examine whether this sex-difference in math ability across the disciplines holds in other countries as well. In light of equal opportunities for boys and girls in education, a higher entry level for STEM participation for girls as compared to boys is undesirable. We suggest that exploring this presumably unintentional sex-difference internationally may also shed some light on the ongoing STEM debate in the Netherlands, because currently it is unclear whether or not this sex-difference within the SCIENCE group is typically Dutch.

Secondly, we examined the relative importance of math ability, AAM, and homework time in explaining differences in SCIENCE students' $GPA_{science}$. We found significant positive effects of math ability and AAM on SCIENCE students' $GPA_{science}$, which confirms Hypotheses 2 and 3. These findings largely support Schiefele and Csikszentmihalyi's (1995) conclusion that ability predicts students' mathematics grades. In our study, however, AAM contributes to student achievement when ability is taken into account. A significant effect of AAM is also in line with studies by Reynold and Walberg (1992), Singh et al. (2002), and Shores and Shannon (2007), which show important contributions of motivation on students' mathematics achievement independent of students' prior achievement. However, our results are in large contrast with Gagné and St.Père (2001), who did not find significant effects of motivational aspects on students' general GPA.

Contrary to findings of Cooper et al. (2006), we did not observe a positive relationship between homework time and SCIENCE students' $GPA_{science}$. In other words, Hypothesis 4 could not be confirmed. Possibly, students who pursue SCIENCE might not need to spend a lot of time on their homework to achieve well in advanced mathematics, chemistry, and physics. Our measure of homework time, which is measured for all school subjects together, might have contributed to this deviation from the results of Cooper et al. (2006). Another plausible explanation is given by Trautwein (2007), who emphasises that other aspects of homework behaviour, for instance homework frequency and homework effort, should be included in research on the relationship between homework behaviour and student achievement to control for important confounding variables (e.g. Callahan & Rademacher, 1998; Pezdek & Berry, 2002; Trautwein, Köller, Schmitz, & Baumert, 2002). Interestingly, we did find a suppression effect of homework time when homework time was added to the regression analyses. In other words, the relationship between AAM and $GPA_{science}$ was stronger when homework time was added than before controlling for this aspect. Additional analysis showed that AAM was stronger related to $GPA_{science}$ for students who spent little time on their homework than for students who spent a lot of time on their homework.

Furthermore, when exploring additional moderating effects of math ability, AAM, and homework time on SCIENCE students' $GPA_{science}$, we did not find significant interaction effects among math ability, AAM, and homework time. The absence of a significant interaction between math ability and homework time suggests that the compensation model as presented by De Klerk et al. (1989), in which homework time moderates the relationship between math ability and $GPA_{science}$, is not very plausible. Because the interaction between math ability and AAM was not significant, the latter did not moderate the relationship between math ability and $GPA_{science}$ either. Hence, our results are in slight contrast with the results of Edwards and Waters (1981) and Hirschfeld et al. (2004), who observe a significant moderating effect of achievement motivation on the relationship between ability and students' GPA. In the current study, math ability and AAM combine additively instead of multiplicatively in predicting $GPA_{science}$. Possibly, a more context-specific measure of achievement motivation, for example students' motivation to do especially well in mathematics and/or science, could have shown different results (Tempelaar et al., 2007), as well as other measures of achievement motivation reported on in recent years (e.g. Deci & Ryan, 2000; Elliot & McGregor, 2001; Pintrich, 2000). Finally, the three-way interaction among math ability, homework time, and academic achievement motivation was not significant, that is, the interaction between academic achievement motivation and homework time did not differ across the various levels of math ability.

A limitation of the present study was the small sample of SCIENCE students for which additional information was available (in particular in track B). However, despite previously reported differences between the response and non-response groups in the SCIENCE sample, we believe that generalising the results to the SCIENCE student population in the Netherlands is justifiable, since it concerned mainly small differences. Nevertheless, repeating the study in a larger sample is desirable. In addition, replicating the findings of the relationships among AAM, homework time, and math ability in a sample of all students (i.e. not only SCIENCE students) would strengthen the results, although our sample of SCIENCE students did not differ from the other students in our sample concerning their AAM or average homework time. Moreover, causal inferences can not be made based on this non-experimental design, albeit math ability, AAM, and homework time were measured preceding the FSE results.

Conclusion

In conclusion: is taking the FSE in advanced mathematics, chemistry, and physics (the SCIENCE profile) attainable by more students in upper secondary education than is currently the case? Our study reveals that students who pursue SCIENCE, and in particular girls, score higher on math ability than students who follow other profiles. These findings suggest that the mandatory combination of advanced mathematics, chemistry, and physics might discourage girls more than boys to choose SCIENCE, which is an important issue for future campaigns to increase girls' enrolment in SCIENCE. Additional research is needed to examine how many students possess the level of math ability required for pursuing SCIENCE. In contrast with students' perception that SCIENCE is too difficult for them, our results show that only a small part of the variance in students' $GPA_{science}$ can be explained by math ability and that AAM is just as important.

As our data suggest, an important implication for actual practice is that math ability should not be the predominant issue for teachers, student counsellors, and tutors when advising students on their study profile choice. The focus of their advice should mainly be on students' interests and ambitions and not only on students' ability in certain school subjects. Of course within schools, math ability is assessed differently than the measure we used in our study, with grades given by the teachers (e.g. based on smaller assignments and tests). Although less objective, students' grades probably have a larger impact on students' self-concept concerning their math/science achievement and on teachers' evaluation of their ability. Based on our findings, we suggest that teachers and student counsellors should clearly identify why they, in some cases, discourage students from pursuing SCIENCE (for example girls with average grades on math/science), since students' examination grades in advanced mathematics, chemistry, and physics are influenced by more than just their math ability. The study of Sternberg (1999) is important here. He argues that human abilities (e.g. math abilities) are forms of developing expertise and therefore can be taught. Applying his theory to our sample, SCIENCE students had higher math ability than other students not only because they achieved better on the math achievement tests we used in the lower grades, but also because their increased motivation to study math/science activated their learning and thinking skills in this area (Sternberg, 1999). Therefore, we suggest that a partly postponed study profile choice might increase the amount of students eventually choosing the SCIENCE profile and/or a STEM study in higher education. For example, 9^{th} grade students should choose a broad package of school subjects, science-oriented (combination of SCIENCE and HEALTH) or society-oriented (combination of ECONOMY and CULTURE). Then, the year before their FSE, students should choose their definitive study profile and study these subjects in more detail. In this system students would have more time to develop their expertise (Sternberg, 1999) in, for example, mathematics and, accordingly, have more time to develop interest in mathematics, chemistry, and physics. However, the magnitude of the effects observed implies that future research should include other relevant factors that have an impact on students' choices and students' examination grades in advanced mathematics, chemistry, and physics. These factors are, for instance, socioeconomic status, ethnicity, students' interest in science subjects, students' efforts during class, and students' attitudes towards science subjects (see for example Oliver & Simpson, 1988). Increasing girls' self-concept concerning their math ability could increase girls' entry in math/science subjects and STEM studies in higher education. Subsequently, the consequences of pursuing SCIENCE with relatively low math ability should be examined. It should be investigated which studies these students choose in higher education and how they perform in comparison with students with a relatively high math ability. In sum, the current paper demonstrates the relative importance of math ability, achievement motivation, and homework time for attainment in advanced mathematics and science courses. This study was conducted to contribute to the existing knowledge about the relations among these variables and to help find a solution to the low number of students - both Dutch and other European students - who take their FSE in advanced mathematics, chemistry, and physics.

Chapter 6

Students' Stereotypes and Perceptions of Science-Oriented Studies*

Abstract

Do non-STEM students' stereotypical views about STEM studies (i.e. science, technology, engineering, and mathematics) correspond with how STEM students actually perceive these studies? This chapter deals with this issue by comparing the attitudes towards STEM studies of STEM students with those of non-STEM students in higher education. The attitudes of the first category of students have been referred to as stereotypes and those of the second category as perceptions. The study included 1,935 students in higher education. The results confirm both small and large differences between the stereotypes and perceptions, and show significant differences between suitably qualified students (i.e. eligible to STEM studies) and other students. At the end of this chapter we will discuss the implications of this study for future research and offer some suggestions for practice.

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Introduction

Despite the reasonable science proficiency levels of students in most OECD countries schools fail to interest students in science-related careers (Organisation for Economic Co-operation and Development, 2009). The majority of the students in secondary education are aware of the importance of science (Parkinson, Hendley, & Tanner, 1998), but many of them tend to choose other disciplines when continuing their study in higher education. One of the main reasons for this phenomenon is that many students do not enjoy science lessons, even if they perform well. Although many high performing secondary education students have a general interest in a scientific career, still 45% is not interested in a science study (OECD, 2009). As a response to European agreements aimed at increasing students' entry in so-called STEM studies (science, technology, engineering, and mathematics) in higher education (European Commission, 2002, 2004), the Dutch government attempts to motivate students to enrol in these disciplines (Ministry of Education, Culture and Science, 2004). In addition, the government seeks to reduce the imbalance between men and women within this sector. A complicating factor is the Dutch educational system, in which students have to decide already at a relatively young age about their future career path. At the end of the 9th grade, when they are on average 15 years old, students must choose one out of four combinations of school subjects (the so-called study profiles[1]). The study profile which includes the combination of advanced mathematics, chemistry, and physics (the science & technology study profile) is the best preparation for a science-oriented study in higher education. Students who have chosen a less science-oriented study profile (e.g. the science & health profile) are eligible only with additional requirements; they generally have to take additional advanced physics courses to meet the entry-criteria. Hence, the study profile choice in secondary education is the first moment in the system when sufficiently talented students leave the STEM-pipeline (Van Langen & Dekkers, 2005). In this way, the educational system works as a narrowing funnel; at each choice moment the possibilities for a transition to a STEM career decrease (De Grip & Willems, 2003). The first moment is the study profile choice in the 9th grade, the second the study choice made at the end of secondary education, and the third the career choice after graduation. Our study has particularly focussed on the second moment, that is, the study choice at the end of secondary education.

Why do so many students whose performance in math/science is fairly sufficient not take STEM studies into consideration while others do? Negative attitudes influence the perceived suitability of particular studies or careers. Several research projects indicate negative attitudes of a considerable amount of students towards science-oriented studies;

[1] See the method section for more information regarding the study profiles.

they are under the impression that these studies are uninteresting (in comparison to other studies), too demanding and difficult, too much technology- or theory-driven or too narrowly focussed (Fuller, 1991; Second Phase Advisory Point, 2005; Verhorst & Verhulst, 1993; Warps, 2001). Apart from these content-based preconceptions, students, in particular girls, argue that the career possibilities in this area are unattractive in comparison to those offered by other studies. Lightbody and Durndell (1996) found that students partly choose their careers by matching their own self-concept, or identity, with their representation of an occupational role (see also Markus & Nurius, 1986). Many women favour studies and careers that contribute to playing a useful social role in society, for example, a law or medicine study (Lightbody & Siann, 1997; Lips, 1992). In addition, several students feel that, although they have completed mathematics and science courses in secondary education, they are not sufficiently capable of pursuing a science-oriented career. De Grip and Willems (2003) established that girls hardly choose technological or science-oriented studies, even when their grades in mathematics and science subjects are high. Trusty and Robinson (2000) report that girls base their postsecondary educational choices on their reading performance rather than on their mathematics skills. Unfamiliarity with the content of STEM studies may drift sufficiently capable students (e.g. students who have completed advanced math and science courses in secondary education) in other directions. Moreover, the full scope of career options actually available is often broader than students' knowledge of the actual range of possible study choices. Through socialization by peers, parents, and teachers, students' personal set of choice options often remains limited (Eccles, 2005; Gottfredson, 1981; Lent, Brown, & Hackett, 1994). In the light of the current desire to increase the number of students who opt for a STEM study, a career in science and technology should not be eliminated simply because of a lack of information or stereotypical ideas (Packard & Nguyen, 2003). Accordingly, in view of adequate counselling it is important to know the views of (sufficiently capable) students with respect to STEM studies and to establish which ideas are, to some extent, irrational. Are STEM studies really uninteresting or too narrowly focussed? This is the one of the main topics of the current study.

While some students independently choose a science-oriented study and thus have clear ideas about its advantages and disadvantages (the "reality"), others have no experience in this field (e.g. they study economics). We have dealt with this issue by comparing the attitudes towards STEM studies of those with experience in STEM with the attitudes of those without experience in STEM. For the first group, we could measure the students' attitudes towards their current STEM study on the basis of their *perceptions*, which – although in essence subjective – were based on real experiences. For those who had no experience with a STEM curriculum, we could only measure their ideas about this type of studies, usually based on more general notions or expectations, for example on the expected difficulty level. For the sake of interpretation we refer to *stereotypes* when we talk about the attitudes of students who have never participated in a STEM study. Students' stereotypes of STEM studies are self-generated, resulting from inference processes which are either indirectly formed by accepting information from external sources (e.g. friends, television, and books), or through direct observations in prior math/science classes (Ajzen & Cote, 2008). Non-STEM students have taken math/science lessons in primary and secondary education, they may have visited an orientation day of a STEM study, they may have read additional information in folders or on the Internet, or talked with their parents and peers about these studies. Non-STEM students' stereotypes can therefore be biased. They may be irrational, based on invalid or selective information, self-serving, or otherwise in contrast with reality (Ajzen & Cote, 2008). A comparison of non-STEM students' stereotypes and STEM students' perceptions provides useful information about possible discrepancies between expectations and experiences. If, for example, student advisors and teachers are aware of certain discrepancies (e.g. between stereotyped and perceived career possibilities of STEM studies), they can use this information in providing better counselling.

Hence, the main objective of the present study has been to investigate to what extent non-STEM students' stereotypes of STEM programmes differ from STEM students' perceptions of these studies. For this purpose, we first examined non-STEM students' stereotypes of STEM studies by focussing on the question: what are these students' stereotypes of STEM studies? Secondly, we explored all (non-STEM and STEM) students' perceptions of their current study. The aim was to examine whether the perceptions of the students who had opted for a science study differed from those who had chosen a technical study (e.g. science studies might be perceived as more difficult than technical studies) and whether the perceptions of STEM-students differed from those of non-STEM students (e.g. both science and technical studies might be perceived as more difficult than other studies). In the main analyses presented in this chapter the STEM students' perceptions of their current STEM study have been used as an indicator of the "true" characteristics of STEM studies. Subsequently, we compared the non-STEM students' stereotypes with the STEM students' perceptions of STEM studies.

Since the STEM discipline is fairly broad, we made a distinction between science studies (e.g. mathematics, physics, chemistry) and technical studies (e.g. industrial engineering, architectural engineering, electrical engineering). Consequently, three groups of students were examined: (A) students who chose a science study, (B) students who opted for a technical study, and (C) students who enrolled in other studies (e.g. law, medicine, and economics). Within these groups, we made a distinction between students who were "suitably qualified" for STEM and those who were not[2]. Suitably qualified

[2] We found both SCIENCE students as well as non-SCIENCE students in all groups. This indicates that some non-SCIENCE students had taken additional courses to meet the entry-requirements of the STEM study they chose.

students were defined as students who have taken their Final School Examinations (FSE) in secondary education in advanced mathematics, chemistry, and physics[3]. In the Netherlands, these are students who have completed the so-called science & technology study profile[4] (hereafter called SCIENCE), which gives them access to all STEM studies in higher education. From now on we will therefore refer to suitably qualified students as SCIENCE students and to all other students as non-SCIENCE students. We were particularly interested in the SCIENCE students in group C, because although these students were eligible for STEM they chose a non-STEM study in higher education (i.e. they did not utilize their science talent). Additionally, we made a distinction between boys and girls. All in all, these distinctions resulted in 12 groups of students (3x2x2).

Hypotheses

We have tested several hypotheses. The first three concern non-STEM students' stereotypes of STEM studies. Since in general more students enter technical than science studies[5] (Statistics Netherlands, 2010), we expected that:

Hypothesis 1: Non-STEM students' stereotypes of technical studies are more favourable than these students' stereotypes of science studies.

To test the first hypothesis, we selected students from group C (who had not chosen a science-oriented study in higher education) and examined their stereotypes of science studies and technical studies.

In addition, we considered it likely that a general interest and an adequate performance in advanced mathematics, chemistry, and physics in secondary school would have a positive effect on students' stereotypes of STEM studies in higher education. The students in our sample who had chosen the SCIENCE study profile were therefore expected to have more favourable views about both categories of science-oriented studies than those who had no experience with advanced math and science classes. The second hypothesis addresses this issue:

Hypothesis 2: SCIENCE students' stereotypes of science and technical studies are more favourable than non-SCIENCE students' stereotypes of these studies.

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3 All students take part in the FSE at the end of secondary education. These national examinations are designed by specialists at the Dutch National Institute for Educational Testing (Cito). The school subjects in which the students took their FSE in the VOCL'99 sample were retrieved from Statistics Netherlands.

4 See the method section for more information regarding the study profiles.

5 In 2007/2008, 6% of the overall group of first year students in higher education chose a science study whereas 9% of this group enrolled in a technical study (Statistics Netherlands, 2010).

In general, girls have less favourable attitudes towards math/science than boys (Frost, Hyde, & Fennema, 1994). As a consequence, few girls opt for the SCIENCE study profile in secondary school (Statistics Netherlands, 2010; Van Langen, Rekers-Mombarg, & Dekkers, 2008). We therefore expected that girls who did choose SCIENCE were particularly interested in math- and science-related topics. For boys to choose SCIENCE is considered more "normal". Moreover, with respect to math-related tests SCIENCE girls on average outperformed SCIENCE boys, whereas non-SCIENCE boys outperformed non-SCIENCE girls (Korpershoek, Kuyper, Van der Werf, & Bosker, 2010). These findings led to our third hypothesis:

Hypothesis 3: As regards science and technical studies SCIENCE girls' stereotypes are more favourable than those of SCIENCE boys, whereas non-SCIENCE girls' stereotypes are less favourable than those of non-SCIENCE boys.

Secondly, exploratory analyses were included to analyze all students' perceptions of their current study and, particularly, STEM students' perceptions of their current STEM study. We have included the descriptive results of the perceptions of all student groups (A, B, and C) of their current study.

The final three hypotheses concern the comparison between stereotypes and perceptions. The stereotypes of the students in group C (other studies) were compared with the perceptions of the students in groups A (science study) and B (technical study). Since choosing a study in higher education is an important decision for students' future career, they are likely to choose a study in which they feel competent and regarding which they have a positive attitude or at least a more favourable one than towards other studies. Students are expected to recognize and include the importance and consequences of their study choice in their decision process. Therefore they are presumed to choose the best suitable option in terms of their abilities, interests, and future perspectives. Based on this principle from behavioural decision theory (see for example Ajzen & Fishbein, 1980) we argued that, in general, the non-STEM students' stereotypes of STEM studies would be less favourable than the STEM students' perceptions of these studies, because the first group (non-STEM students) had not chosen a STEM study, whereas the second group (STEM students) had. This premise formed the basis of our fourth hypothesis:

Hypothesis 4: Non-STEM students' stereotypes of STEM studies are less favourable than STEM students' perceptions of these studies.

Since we assumed SCIENCE students to have a general interest in math- and science-related topics, and non-SCIENCE students who had chosen a STEM study to be highly motivated in their switch to STEM (e.g. they had to take additional courses to become eligible for STEM), Hypothesis 5 states that:

Hypothesis 5: Non-STEM students' stereotypes of STEM studies are more favourable among SCIENCE students than among non-SCIENCE students, whereas STEM students' perceptions of STEM studies are more favourable among non-SCIENCE students than among SCIENCE students.

And finally, because the attitudes of girls towards mathematics are generally less positive (Frost et al., 1994), and girls are overall less interested in math/science than boys (Elsworth, Harvey-Beavis, Ainley, & Fabris, 1999), we formulated our last hypothesis[6] as follows:

Hypothesis 6: Non-STEM girls' stereotypes of STEM studies are less favourable than non-STEM boys' stereotypes of STEM studies, whereas STEM girls' perceptions of STEM studies are more favourable than STEM boys' perceptions of STEM studies.

Method

Participants

The data used in this study were collected as part of a large-scale longitudinal study in the Netherlands, the "Cohort Studies in Secondary Education" (VOCL'99). In this study students are being followed in their educational career from the 7th grade (age 12) onwards until they leave the full-time educational system. The overall sample has been considered representative of the schools and students in Dutch secondary education (Van Berkel, 1999). For more information on the VOCL'99 study we refer to Korpershoek, Kuyper and Van der Werf (2006), and Kuyper and Van der Werf (2003, 2005). In January 2008, a follow-up questionnaire was sent to a subsample of the students from the VOCL'99 cohort, that is, to students who had completed the secondary school tracks A or B (the tracks that prepare students for higher education). The questionnaire addressed several topics among which students' study choices and several attitudinal variables. The overall response to the questionnaire was 32% (Rekers-Mombarg, Korpershoek, Kuyper, & Van der Werf, 2010). The data used in the present study include students from the response

[6] Although it would be interesting to investigate the three-way interaction-effect of the construct (stereotype or perception) x study profile x sex, this has not been included in the present study because the sample sizes for some of the cells were too small for this purpose (e.g. non-SCIENCE girls who pursue a technical study).

group who participated in a higher education study during the data collection (i.e. higher professional education or university; mostly second or third year students). The selection resulted in 1,935 students who were included in the analyses. As stated in the previous section, the respondents included were divided into three groups: (A) students who had chosen a science study (e.g. mathematics, physics, or chemistry; 120 students), (B) students who had opted for a technical study (e.g. industrial engineering, architectural engineering, or electrical engineering; 186 students), and (C) students who had enrolled in other studies (e.g. medicine, law, economics; 1629 students). Table 1 shows additional information on the respondents included.

Table 1 *Participants categorised by student group*

	N	% science study (group A)	% technical study (group B)	% other study (group C)
SCIENCE boys[a]	201	22.4	57.2	20.4
SCIENCE girls[a]	37	27.0	29.7	43.2
Non-SCIENCE boys[b]	479	6.3	9.6	84.1
Non-SCIENCE girls[b]	1,218	2.9	1.1	96.0
Total	1,935	6.2	9.6	84.2

Notes. [a] Students who took their Final School Examinations (FSE) in secondary education in advanced mathematics, chemistry, and physics; [b] Students who did not take their FSE in secondary education in advanced mathematics, chemistry, and physics.

In the sample girls are largely overrepresented (65%). With respect to student study profile choice the sample is, however, representative of the Dutch student population, that is, 30% of the boys and 3% of the girls took their FSE in the SCIENCE study profile.

Variables and instruments

Study choices. In the questionnaire, students were asked in which area they studied at that time: science (coded group A), technical (coded group B), or another discipline (coded group C). The students were also provided with the earlier mentioned examples of particular studies within these three disciplines.

Stereotypes. The non-STEM students' stereotypes of science-oriented studies were measured by using twelve items. These items were in previous research found to be important issues for students when making educational choices. The answer categories were based on a 1 to 7 scale (e.g. from *very few* to *very much*). Students were asked whether they expected a science-oriented study to be: (1) difficult or easy (e.g. "Do you think that a science study is difficult or easy?") (2), narrowly focussed or broadly oriented, (3) uninteresting or interesting, (4) including few or many theoretical courses, (5) including few or many options to specialize, (6) including few or many additional choice options, (7) a study in which they would achieve well, (8) a study which would contribute to their development in general, (9) generally suitable ("fits me"), (10) helpful in finding an attractive job within six months after their graduation, (11) suitable for preparing them for a useful job in society, and (12) suitable for preparing them for one or more job opportunities. The students had to answer these questions for both science and technical studies. Students of groups A and B (science-oriented studies) did not have to respond to these questions. For 6 students some of the science study item scores were not available (<1% non-response). This was the case with 15 students for the technical study items (1% non-response).

Perceptions. The students' perceptions of their studies were measured by using items that were similar to the 12 items listed in the previous paragraph (e.g. "Do you find your study difficult or easy?"), again with answer category scales from 1 to 7. For 6 students some of the item scores were not available (<1% non-response).

Sex. Sex (girls coded 0; boys coded 1) was measured in an earlier stage of the longitudinal VOCL'99 study, namely in the first year of secondary education (7th grade). This information was provided by the schools.

Study profiles. At the end of the 9th grade, students preparing for higher education choose one out of four possible combinations of school subjects, called "study profiles", in which they take their FSE. Next to science & technology (SCIENCE), students can choose science & health (HEALTH), economics & society (ECONOMY), or culture & society (CULTURE), or a combination of two profiles. Apart from subjects that are common in all profiles (e.g. Dutch and English language), SCIENCE and HEALTH students take their FSE in advanced mathematics, chemistry, and physics. In the HEALTH profile less time is spent on these subjects, as their content is more elementary and less science-oriented than in the SCIENCE profile. The HEALTH profile also includes biology. The ECONOMY and CULTURE profiles roughly consist of applied mathematics (both), history (both), economics (ECONOMY), and modern languages (CULTURE). Formally, the study profile choice is unrestricted and based on students' interests and ambitions. However, the actual decision of a student is usually made in interaction with parents, teachers, and school counsellors, and can therefore be curtailed to some extent. For the present study, we divided the students into suitably qualified students (i.e. for entering STEM studies) and not suitably qualified students, that is, into SCIENCE students and non-SCIENCE students, respectively.

Results

Non-STEM students' stereotypes of STEM studies

We first investigated non-STEM students' stereotypes of science studies and technical studies. Table 2 presents the results for group C students (i.e. students who did not enrol in a science-oriented study).

Table 2 *Students' stereotypes (group C) of science-oriented studies (means and standard deviations)*

	SCIENCE[a]	Non-SCIENCE[b]	Boys	Girls	Total
Science studies:					
Difficulty level	3.1 (1.1) ***	2.2 (1.1)	2.5 (1.2)	2.1 (1.1)	2.2 (1.1)
Varied content	3.5 (1.5)*	3.3 (1.4)	3.2 (1.5)	3.4 (1.4)**	3.3 (1.4)
Interesting	4.1 (1.6)***	3.1 (1.7)	3.2 (1.7)*	3.1 (1.7)	3.1 (1.7)
Theoretical courses	5.9 (1.1)	5.7 (1.2)	5.9 (1.2)	5.7 (1.2)	5.7 (1.2)***
Specialization options	4.8 (1.5)	4.7 (1.6)	4.8 (1.6)	4.6 (1.5)	4.7 (1.5)
Options to choose	4.1 (1.4)	4.1 (1.4)	4.0 (1.4)	4.1 (1.3)	4.1 (1.4)
Achievement	4.2 (1.4)***	2.9 (1.6)	3.3 (1.6)	2.8 (1.6)	2.9 (1.6)**
General development	3.8 (1.5)	3.6 (1.4)	3.5 (1.5)	3.7 (1.4)*	3.6 (1.4)
Fits me	3.7 (1.7)***	2.5 (1.5)	2.8 (1.5)	2.4 (1.5)	2.5 (1.5)*
Job within half a year	4.8 (1.4)	4.5 (1.4)	4.5 (1.5)	4.5 (1.3)	4.5 (1.4)
Job useful for society	4.7 (1.2)***	4.2 (1.3)	4.1 (1.4)	4.2 (1.3)	4.2 (1.3)
Different job opp.	4.1 (1.4)	4.1 (1.4)	4.0 (1.5)	4.1 (1.4)*	4.1 (1.4)
Technical studies:					
Difficulty level	3.1 (1.2) ***	2.2 (1.1)	2.7 (1.2) ***	2.0 (1.0)	2.2 (1.1)
Varied content	4.4 (1.3)*	4.1 (1.4)	4.2 (1.4)	4.0 (1.4)	4.1 (1.4)***
Interesting	4.5 (1.3)***	3.0 (1.7)	3.8 (1.7)**	2.8 (1.6)	3.1 (1.7)
Theoretical courses	4.9 (1.2)	4.6 (1.4)	4.6 (1.4)	4.7 (1.5)	4.7 (1.4)
Specialization options	5.3 (1.3)	5.3 (1.2)	5.5 (1.2)	5.2 (1.2)	5.3 (1.2)***
Options to choose	5.0 (1.1)	4.7 (1.1)	4.9 (1.2)	4.7 (1.1)	4.8 (1.1)***
Achievement	4.6 (1.4)***	2.8 (1.4)	3.5 (1.5)***	2.6 (1.4)	2.8 (1.5)
General development	4.4 (1.3)**	3.9 (1.3)	4.1 (1.4)	3.8 (1.3)	3.9 (1.3)***
Fits me	4.3 (1.5)***	2.4 (1.4)	3.1 (1.6)***	2.2 (1.3)	2.4 (1.4)
Job within half a year	5.4 (1.1)	5.1 (1.2)	5.1 (1.2)	5.1 (1.2)	5.1 (1.2)***
Job useful for society	5.0 (1.3)*	4.8 (1.2)	4.7 (1.2)	4.8 (1.2)*	4.8 (1.2)***
Different job opp.	5.2 (1.2)*	4.8 (1.2)	4.9 (1.2)	4.9 (1.2)	4.9 (1.2)***

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$; [a] Students who took their Final School Examinations (FSE) in secondary education in advanced mathematics, chemistry, and physics; [b] Students who did not take their FSE in secondary education in advanced mathematics, chemistry, and physics.

Paired samples t-tests (one-tailed) were performed for each item to test whether students' stereotypes of technical studies were more favourable than their stereotypes of science studies (Hypothesis 1). The results are included in the final column of Table 2. Note that the asterisks for the *p*-values are placed at the highest average (e.g. students expect more theoretical courses in science studies than in technical studies, so we placed the asterisk next to the science study score on that item). In order to test Hypothesis 2 (SCIENCE students' stereotypes of science and technical studies are more favourable than non-SCIENCE students' stereotypes of these studies), analyses of variance were computed for each item (separately for science and technical studies), using SCIENCE/non-SCIENCE and sex, and the interaction between them as independent variables (again we used one-tailed tests for the significance levels). These results are also included in Table 2. The asterisks refer to the significant main effects.

In general, the students' stereotypes of STEM studies are positive (i.e. scores > 4, which is the centre of the Likert scale), both for *specialization options* and *options to choose* as well as for the job-related items and the content variety expected (the latter only applying to technical studies). Whether the > 4 score on *theoretical courses* is a positive or negative stereotype is debatable. The score on expected *difficulty level* (difficult or easy) represents (for most students) a negative stereotype, as well as the scores < 4 on the items *interesting, achievement, general development, fits me*, and *varied content* (the latter only applying to science studies).

The students' stereotypes of technical studies are, in the case of most items, more favourable than those of science studies, which confirms our expectations (Hypothesis 1). Cohen's d for the effect sizes was used to interpret the effects (the effect sizes ≥ 0.20 are presented here). The results show that as far as the students were concerned science studies have a less varied content (Cohen's d = -0.57), fewer specialization options (-0.44), fewer options to choose (-0.56), they contribute less to their general development (-0.22), and offer less favourable career perspectives (effect sizes of respectively -0.46 for *job within six months*, -0.48 for *job useful for society*, and -0.61 for *different job opportunities*). In addition, science studies were expected to offer more theoretical courses than technical studies (0.77).

In general, we found support for the second hypothesis that SCIENCE students' stereotypes of STEM studies are more favourable than non-SCIENCE students' stereotypes of these studies. The largest effects we observed between SCIENCE and non-SCIENCE students concerning stereotypes of science studies were produced by the items *difficulty level* (Cohen's d = -0.82), *interesting* (-0.59), *achievement* (-0.82), and *fits me* (-0.80). A smaller effect was found for the item *job useful for society* (-0.39). Concerning the stereotypes of technical studies the largest effects between SCIENCE and non-SCIENCE students were generated by the items *difficulty level* (-0.82), *interesting* (-0.89), *achievement* (-1.29), and *fits me* (-1.35). A smaller effect was found for the item *general development* (-0.38).

In addition, we detected several main effects of sex concerning students' stereotypes of technical studies. Moderate effects were discerned for the items *difficulty level* (-0.66), *interesting* (-0.61), *achievement* (-0.63), and *fits me* (-0.65). For these items the girls' stereotypes were less favourable than those of the boys. For the science studies these sex differences were similar, albeit not significant. With respect to the stereotypes of science studies significant interaction-effects were found between SCIENCE/non-SCIENCE and sex for the items *fits me* and *different job opportunities* ($p < .01$) and for *difficulty level, varied content*, *interesting*, and *achievement* ($p < .05$). These results partly confirmed our expectations. SCIENCE girls' stereotypes of these items were, in general, more favourable than those of SCIENCE boys, whereas those of non-SCIENCE girls were less favourable than those of non-SCIENCE boys. None of the corresponding effect sizes were larger than 0.20. With respect to technical study stereotypes we found one significant interaction-effect between SCIENCE/non-SCIENCE and sex, namely for the item *job useful for society* ($p < .05$; Cohen's $d < 0.20$). Therefore, Hypothesis 3 was supported for 6 of the 12 items concerning the science study stereotypes and for 1 of the 12 items concerning the technical study stereotypes.

Students' perceptions of their current study

In this paragraph, we present the descriptive results of our exploratory analyses of the students' perceptions of their study at the time of our research. The aim was to examine whether the perceptions of groups A and B differed (e.g. science studies might be perceived as more difficult than technical studies) and whether the perceptions of groups A and B differed from group C (e.g. both science and technical studies might be perceived as more difficult than other studies). Table 3 shows the main results based on the items for groups A, B, C, SCIENCE students, non-SCIENCE students, boys, girls, and the overall student group. The overall standard deviations have been included in the overall mean per item in the final column. Since the differences between SCIENCE and non-SCIENCE students and between the sexes largely overlap with the differences among groups A, B, and C (see Table 1), Table 3 only presents the main differences. The differences among the four groups (non-SCIENCE boys, non-SCIENCE girls, SCIENCE boys, and SCIENCE girls) are discussed in the analyses in the next section.

We can see that in general the students' perceptions of their current study are positive (i.e. scores > 4) and consistent across the items. The mean score on *difficulty level* is slightly lower than the other mean scores. As regards difficulty level a higher score (i.e. very easy) is not necessarily more favourable than a lower score (i.e. very difficult), whereas for the other items a higher score is usually more favourable (e.g. more interesting, better future perspectives). The results in Table 3 show that the students from group C (other studies) perceive their study as less difficult than the students from groups A (science studies) and B (technical studies). Moreover, group A students perceive their study as less difficult than group B students. Additionally, group C students feel that their study contributes a lot to their general development as compared to the students who chose a science or technical study. Science and technique students scored higher on perceived future perspectives of their study (*job within six months* and *different job opportunities*) than students engaged in other studies. However, no substantial differences have been found among the student groups (A, B, and C).

Table 3 *Students' perceptions of their current study (means and standard deviations)*

	A[a]	B[a]	C[a]	SCIENCE[b]	Non-SCIENCE[c]	Boys	Girls	Total
Difficulty level	3.5	3.8	4.0	3.7	3.9	3.9	3.9	3.9 (1.1)
Varied content	5.3	5.3	5.4	5.3	5.4	5.3	5.4	5.4 (1.1)
Interesting	5.8	5.7	5.8	5.8	5.8	5.7	5.8	5.8 (1.0)
Theoretical courses	5.3	5.0	4.8	5.0	4.9	5.0	4.8	4.9 (1.4)
Specialization options	5.3	5.1	5.0	5.3	5.0	5.2	4.9	5.0 (1.4)
Options to choose	4.9	4.7	4.8	4.8	4.8	4.8	4.8	4.8 (1.4)
Achievement	5.0	5.1	5.2	5.1	5.2	5.1	5.2	5.2 (0.9)
General development	5.1	5.1	5.7	5.2	5.6	5.4	5.7	5.6 (1.1)
Fits me	5.6	5.6	5.8	5.6	5.8	5.6	5.8	5.7 (1.0)
Job within half a year	5.9	6.0	5.1	5.9	5.2	5.6	5.1	5.3 (1.3)
Job useful for society	5.5	5.4	5.7	5.4	5.7	5.4	5.8	5.7 (1.2)
Different job opp.	5.5	5.6	5.3	5.5	5.3	5.5	5.3	5.3 (1.5)

Notes. [a] A = science studies, B = technical studies, C = other studies; [b] Students who took their Final School Examinations (FSE) in secondary education in advanced mathematics, chemistry, and physics; [c] Students who did not take their FSE in secondary education in advanced mathematics, chemistry, and physics.

Differences between non-STEM students' stereotypes and STEM students' perceptions of STEM studies

In this section, we present our main analysis: the comparison between non-STEM students' stereotypes of STEM studies and STEM students' perceptions of STEM studies. Table 4 shows the descriptive results. It presents the mean differences (average perception minus average stereotype) between perceptions and stereotypes of science and technical studies per item for SCIENCE students, non-SCIENCE students, boys, girls, and the overall difference. The average differences between perceptions and stereotypes vary from 0.0 to 3.3 on a 7-point Likert-scale.

Subsequently, we systematically present the descriptive results for each of the 12 items and describe the results of the multiple linear regression analyses by which we statistically tested our hypotheses as stated in the introduction.

We will first discuss the overall differences between stereotypes and perceptions (column "Total" of Table 4). Science studies show relatively large differences (mean difference ≥ 2) for the items *varied content, interesting, achievement* and *fits me*, and the technical studies for the items *interesting, achievement,* and *fits me.* In particular the large difference regarding the item *fits me* (mean difference > 3) is remarkable. Moreover, the difference as regards the *varied content* of science studies reveals that the science students' perceptions of the content variety are more favourable than non-STEM students' stereotypes of this item.

With respect to the other items the differences were less remarkable. These overall results are in line with our expectation that students generally opt for the "best fitting" option when choosing a study. The STEM students' perceptions of science and technical studies are indeed more favourable than the non-STEM students' stereotypes of these studies: overall, the mean differences are positive scores (with some small exceptions).

Table 4 *Mean differences between perceptions and stereotypes*

	SCIENCE[a]	Non-SCIENCE[b]	Boys	Girls	Total
Science studies[c]:					
Difficulty level	0.3	1.4	1.0	1.4	1.3
Varied content	1.8	2.0	2.1	2.0	2.0
Interesting	1.7	2.7	2.7	2.7	2.7
Theoretical courses	-0.7	-0.3	-0.6	-0.4	-0.4
Specialization options	0.5	0.6	0.5	0.7	0.6
Options to choose	0.8	0.7	0.9	0.8	0.8
Achievement	0.9	2.1	1.7	2.3	2.1
General development	1.2	1.5	1.6	1.3	1.5
Fits me	1.9	3.0	2.7	3.3	3.1
Job within half a year	1.2	1.3	1.4	1.3	1.4
Job useful for society	0.5	1.5	1.3	1.3	1.3
Different job opp.	1.8	1.2	1.6	1.4	1.4
Technical studies[d]:					
Difficulty level	0.6	1.7	1.0	2.0	1.6
Varied content	0.9	1.3	1.1	1.4	1.2
Interesting	1.3	2.7	1.9	2.8	2.6
Theoretical courses	0.2	0.2	0.4	0.0	0.3
Specialization options	-0.1	0.2	-0.4	0.0	-0.2
Options to choose	-0.3	0.0	-0.2	0.3	-0.1
Achievement	0.5	2.4	1.6	2.4	2.3
General development	0.7	1.3	1.0	1.3	1.2
Fits me	1.3	3.3	2.6	3.2	3.2
Job within half a year	0.6	0.9	0.9	0.9	0.9
Job useful for society	0.5	0.5	0.7	0.6	0.6
Different job opp.	0.4	0.7	0.7	0.7	0.7

Notes. [a] Students who took their Final School Examinations (FSE) in secondary education in advanced mathematics, chemistry, and physics; [b] Students who did not take their FSE in secondary education in advanced mathematics, chemistry, and physics; [c] Mean perception scores of group A (science students) minus mean stereotype scores of group C (other students); [d] Mean perception scores of group B (technical students) minus mean stereotype scores of group C (other students).

With respect to SCIENCE and non-SCIENCE students, our results in Table 4 indicate that the difference between perceptions and stereotypes is somewhat smaller for SCIENCE students than for non-SCIENCE students. Although the differences reported between SCIENCE students and non-SCIENCE students (all ≤ 2) for the items are not that large, there does appear to be a systematic difference throughout the items.

With respect to sex, the results of Table 4 show that the difference between stereotypes and perceptions of STEM studies are for both sexes generally of the same magnitude (all ≤ 1). For some items the differences the between stereotypes and perceptions of technical studies are slightly larger for girls than for boys, but no systematic sex-difference appears in the table.

To test the three hypotheses related to the comparisons of stereotypes and perceptions statistically, multiple linear regression analyses were conducted. In these analyses, the outcome variables were the scores on the items (e.g. *difficulty level*). The predictors were three dummy variables and their interactions. The first dummy represented the measured construct, that is, whether students' score on the item was a perception (coded 1) or a stereotype (coded 0). The second dummy represented the study profile in which the students took their FSE (SCIENCE coded 1; non-SCIENCE coded 0). The third dummy indicated the sex of the students (boys coded 1; girls coded 0). An alpha of .001 was used to identify significant effects (one-tailed). The main effects of the construct indicated whether the non-STEM students' stereotypes of STEM studies were less favourable than the STEM students' perceptions of STEM studies (Hypothesis 4). Interaction-effects of construct x study profile showed whether the differences between stereotypes and perceptions of STEM studies differed between the non-SCIENCE students and the SCIENCE students (Hypothesis 5), while interaction-effects of construct x sex indicated whether the differences between stereotypes and perceptions of STEM studies differed between the sexes (Hypothesis 6).

The 24 regression analyses showed the following outcomes (see Table 5 for science studies and Table 6 for technical studies). The explained variance (R^2) varied from <1% to 41%. With respect to the science studies more than 10% explained variance was found for the items *difficulty level* (11%), *varied content* (12%), *interesting* (16%), *achievement* (13%), and *fits me* (23%). As regards the technical studies, more than 10% variance was explained for the items *difficulty level* (23%), *interesting* (25%), *achievement* (28%), and *fits me* (41%). We found significant main construct effects for 10 out of the 12 items for the science studies and for 8 out of the 12 items for the technical studies. For both studies, these were the items *difficulty level, varied content, interesting, achievement, general development, fits me, job within half a year, different job opportunities,* and for science studies also *options to choose* and *job useful for society*. In all cases, the STEM students' perceptions of science studies were more favourable than the stereotypes of non-STEM students, which supports Hypothesis 4.

Table 5 *Multiple linear regression analyses for science studies*

			95% confidence interval for *B*	
	B (SE)	*β*	Lower	Upper
Difficulty level (R^2 = .11)				
Constant	2.10 (0.03)		2.04	2.16
Construct (perception vs. stereotype)	1.48 (0.18)	0.31*	1.13	1.82
Study profile (SCIENCE vs. non-SCIENCE)	0.80 (0.15)	0.16*	0.49	1.10
Sex (boys vs. girls)	0.29 (0.06)	0.11*	0.16	0.42
Interaction Construct x Study profile	-1.04 (0.27)	-0.15*	-1.57	-0.51
Interaction Construct x Sex	-0.19 (0.24)	-0.03	-0.65	0.28
Varied content (R^2 = .12)				
Constant	3.37 (0.04)		3.29	3.45
Construct	2.04 (0.22)	0.34*	1.60	2.48
Study profile	0.25 (0.19)	0.04	-0.13	0.63
Sex	-0.23 (0.08)	-0.07	-0.39	-0.07
Interaction Construct x Study profile	-0.20 (0.34)	-0.02	-0.87	0.47
Interaction Construct x Sex	0.07 (0.30)	0.01	-0.51	0.65
Interesting (R^2 = .16)				
Constant	3.05 (0.05)		2.95	3.14
Construct	2.73 (0.26)	0.38*	2.22	3.25
Study profile	1.03 (0.23)	0.14*	0.58	1.48
Sex	0.07 (0.09)	0.02	-0.12	0.25
Interaction Construct x Study profile	-1.04 (0.40)	-0.10*	-1.82	-0.25
Interaction Construct x Sex	0.01 (0.35)	0.00	-0.68	0.70
Theoretical courses (R^2 = .01)				
Constant	5.67 (0.04)		2.60	5.74
Construct	-0.30 (0.19)	-0.06	-0.69	0.08
Study profile	0.09 (0.17)	0.02	-0.24	0.43
Sex	0.19 (0.07)	0.07	0.05	0.32
Interaction Construct x Study profile	-0.22 (0.30)	-0.03	-0.80	0.36
Interaction Construct x Sex	-0.20 (0.26)	-0.03	-0.71	0.30
Specialization options (R^2 = .01)				
Constant	4.62 (0.04)		4.53	4.71
Construct	0.66 (0.24)	0.11	0.19	1.14
Study profile	0.09 (0.21)	0.01	-0.32	0.51
Sex	0.14 (0.09)	0.04	-0.04	0.31
Interaction Construct x Study profile	0.04 (0.37)	0.00	-0.69	0.76
Interaction Construct x Sex	-0.21 (0.32)	-0.03	-0.85	0.42
Options to choose (R^2 = .02)				
Constant	4.08 (0.04)		4.00	4.16
Construct	0.76 (0.22)	0.14*	0.34	1.19
Study profile	0.10 (0.19)	0.02	-0.27	0.47
Sex	-0.08 (0.08)	-0.03	-0.23	0.07
Interaction Construct x Study profile	-0.01 (0.33)	0.00	-0.65	0.64
Interaction Construct x Sex	0.05 (0.29)	0.01	-0.52	0.61

Note. * p < .001.

			95% confidence interval for *B*	
	B (SE)	*β*	Lower	Upper
Achievement (R^2 = .13)				
Constant	2.80 (0.04)		2.71	2.89
Construct	2.26 (0.24)	0.35*	1.79	2.73
Study profile	1.13 (0.21)	0.17*	0.72	1.53
Sex	0.35 (0.09)	0.10*	0.18	0.52
Interaction Construct x Study profile	-0.99 (0.36)	-0.11	-1.71	-0.28
Interaction Construct x Sex	-0.49 (0.32)	-0.06	-1.12	0.13
General development (R^2 = .07)				
Constant	3.68 (0.04)		3.60	3.76
Construct	1.39 (0.22)	0.24*	0.95	1.83
Study profile	0.22 (0.19)	0.04	-0.16	0.60
Sex	-0.18 (0.08)	-0.06	-0.34	-0.02
Interaction Construct x Study profile	-0.45 (0.34)	-0.05	-1.11	0.21
Interaction Construct x Sex	0.35 (0.30)	0.05	-0.23	0.93
Fits me (R^2 = .23)				
Constant	2.41 (0.04)		2.32	2.49
Construct	3.23 (0.23)	0.49*	2.77	3.68
Study profile	1.12 (0.20)	0.16*	0.72	1.52
Sex	0.24 (0.08)	0.07	0.08	0.41
Interaction Construct x Study profile	-0.97 (0.35)	-0.10	-1.66	-0.28
Interaction Construct x Sex	-0.45 (0.31)	-0.05	-1.05	0.16
Job within half a year (R^2 = .06)				
Constant	4.46 (0.04)		4.38	4.54
Construct	1.30 (0.22)	0.23*	0.87	1.72
Study profile	0.28 (0.19)	0.05	-0.09	0.65
Sex	0.01 (0.08)	0.00	-0.14	0.17
Interaction Construct x Study profile	-0.10 (0.33)	-0.01	-0.75	0.54
Interaction Construct x Sex	0.04 (0.29)	0.01	-0.53	0.60
Job useful for society (R^2 = .06)				
Constant	4.20 (0.04)		4.13	4.28
Construct	1.43 (0.21)	0.27*	1.02	1.84
Study profile	0.55 (0.18)	0.10	0.20	0.91
Sex	-0.12 (0.08)	-0.04	-0.27	0.02
Interaction Construct x Study profile	-1.00 (0.32)	-0.13*	-1.62	-0.38
Interaction Construct x Sex	0.19 (0.28)	0.03	-0.36	0.73
Different job opportunities (R^2 = .07)				
Constant	4.10 (0.04)		4.03	4.18
Construct	1.24 (0.22)	0.22*	0.82	1.67
Study profile	-0.01 (0.19)	-0.00	-0.39	0.36
Sex	-0.05 (0.08)	-0.02	-0.21	0.10
Interaction Construct x Study profile	0.65 (0.33)	0.08	-0.01	1.30
Interaction Construct x Sex	-0.10 (0.29)	-0.01	-0.67	0.47

Note. * $p < .001$.

Table 6 *Multiple linear regression analyses for technical studies*

			95% confidence interval for *B*	
	B (SE)	*β*	Lower	Upper
Difficulty level (R^2 = .23)				
Constant	5.99 (0.03)		5.93	6.05
Construct (perception vs. stereotype)	2.09 (0.23)	0.53*	2.53	1.65
Study profile (SCIENCE vs. non-SCIENCE)	0.68 (0.15)	0.17*	0.97	0.39
Sex (boys vs. girls)	0.63 (0.06)	0.25*	0.75	0.51
Interaction Construct x Study profile	-0.89 (0.22)	-0.19*	-0.45	-1.33
Interaction Construct x Sex	-0.84 (0.24)	-0.20*	-0.37	-1.31
Varied content (R^2 = .07)				
Constant	4.03 (0.04)		3.95	4.11
Construct	1.41 (0.30)	0.29*	0.82	1.99
Study profile	0.31 (0.20)	0.06	-0.07	0.69
Sex	0.13 (0.08)	0.04	-0.02	0.29
Interaction Construct x Study profile	-0.39 (0.30)	-0.07	-0.98	0.19
Interaction Construct x Sex	-0.18 (0.32)	-0.04	-0.80	0.44
Interesting (R^2 = .25)				
Constant	2.82 (0.05)		2.73	2.90
Construct	2.77 (0.33)	0.47*	2.12	3.43
Study profile	1.03 (0.22)	0.17*	0.60	1.45
Sex	0.86 (0.09)	0.23*	0.69	1.04
Interaction Construct x Study profile	-1.00 (0.33)	-0.14	-1.65	-0.35
Interaction Construct x Sex	-0.76 (0.35)	-0.12	-1.46	-0.07
Theoretical courses (R^2 = .01)				
Constant	4.68 (0.04)		4.60	4.76
Construct	-0.07 (0.31)	-0.02	-0.67	0.52
Study profile	0.27 (0.20)	0.06	-0.12	0.65
Sex	-0.13 (0.08)	-0.04	-0.29	0.03
Interaction Construct x Study profile	-0.01 (0.30)	-0.00	-0.60	0.58
Interaction Construct x Sex	0.38 (0.32)	0.08	-0.25	1.01
Specialization options (R^2 = .01)				
Constant	5.21 (0.04)		5.14	5.28
Construct	-0.10 (0.26)	-0.03	-0.60	0.40
Study profile	-0.14 (0.17)	-0.03	-0.47	0.19
Sex	0.26 (0.07)	0.10*	0.13	0.40
Interaction Construct x Study profile	0.26 (0.26)	0.05	-0.24	0.76
Interaction Construct x Sex	-0.34 (0.27)	-0.08	-0.87	0.20
Options to choose (R^2 = .00)				
Constant	4.71 (0.03)		4.65	4.78
Construct	0.25 (0.25)	0.07	-0.23	0.74
Study profile	0.23 (0.16)	0.06	-0.09	0.55
Sex	0.13 (0.07)	0.05	0.00	0.26
Interaction Construct x Study profile	-0.25 (0.25)	-0.05	-0.73	0.24
Interaction Construct x Sex	-0.37 (0.26)	-0.09	-0.89	0.15

Note. * $p < .001$.

			95% confidence interval for *B*	
	B (SE)	*β*	Lower	Upper
Achievement (R^2 = .28)				
Constant	2.55 (0.04)		2.48	2.63
Construct	2.48 (0.29)	0.48*	1.92	3.04
Study profile	1.44 (0.19)	0.27*	1.07	1.80
Sex	0.83 (0.08)	0.25*	0.68	0.98
Interaction Construct x Study profile	-1.51 (0.29)	-0.24*	-2.07	-0.96
Interaction Construct x Sex	-0.68 (0.30)	-0.12	-1.28	-0.08
General development (R^2 = .08)				
Constant	3.83 (0.04)		3.76	3.91
Construct	1.33 (0.28)	0.30*	0.78	1.87
Study profile	0.47 (0.18)	0.10	0.12	0.83
Sex	0.18 (0.07)	0.06	0.04	0.33
Interaction Construct x Study profile	-0.66 (0.28)	-0.12	-1.20	-0.12
Interaction Construct x Sex	-0.09 (0.29)	-0.02	-0.67	0.49
Fits me (R^2 = .41)				
Constant	2.15 (0.04)		2.07	2.22
Construct	3.25 (0.28)	0.58*	2.70	3.80
Study profile	1.57 (0.18)	0.28*	1.21	1.93
Sex	0.86 (0.07)	0.24*	0.71	1.00
Interaction Construct x Study profile	-1.66 (0.28)	-0.25*	-2.20	-1.11
Interaction Construct x Sex	-0.52 (0.30)	-0.09	-1.10	0.06
Job within half a year (R^2 = .06)				
Constant	5.08 (0.03)		5.01	5.14
Construct	0.85 (0.25)	0.21*	0.36	1.35
Study profile	0.31 (0.16)	0.08	-0.01	0.64
Sex	0.04 (0.07)	0.02	-0.09	0.17
Interaction Construct x Study profile	-0.24 (0.25)	-0.05	-0.73	0.25
Interaction Construct x Sex	0.01 (0.27)	0.00	-0.51	0.54
Job useful for society (R^2 = .03)				
Constant	4.78 (0.03)		4.71	4.85
Construct	0.53 (0.25)	0.13	0.03	1.03
Study profile	0.23 (0.17)	0.06	-0.10	0.55
Sex	-0.07 (0.07)	-0.03	-0.21	0.06
Interaction Construct x Study profile	-0.11 (0.25)	-0.03	-0.61	0.38
Interaction Construct x Sex	0.06 (0.27)	0.01	-0.47	0.59
Different job opportunities (R^2 = .04)				
Constant	4.85 (0.03)		4.78	4.92
Construct	0.82 (0.25)	0.20*	0.32	1.32
Study profile	0.34 (0.17)	0.08	0.01	0.67
Sex	-0.01 (0.07)	-0.00	-0.14	0.13
Interaction Construct x Study profile	-0.49 (0.25)	-0.10	-0.98	0.01
Interaction Construct x Sex	0.08 (0.27)	0.02	-0.45	0.60

Note. * $p < .001$.

In addition, we found some main effects of study profile and of sex. For both the science and the technical studies the main effects of study profile were significant for the items *difficulty level, interesting, achievement,* and *fits me*. For these items, the SCIENCE students' scores were higher than those of the non-SCIENCE students, indicating that the SCIENCE students' attitudes towards STEM (both perceptions and stereotypes) were more favourable than those of the non-SCIENCE students. The main effects of sex were significant for the items *difficulty level* and *achievement* for both the science and the technical studies, and for the items *interesting, specialization options,* and *fits me* for only the technical studies. For these items, the boys' scores were higher than the girls' scores, indicating that boys' attitudes towards STEM (both perceptions and stereotypes) were more favourable than girls' attitudes towards STEM.

In addition to several main effects, we found three interaction-effects of construct x study profile for the science studies, namely for the items *difficulty level, interesting,* and *job useful for society*. For the technical studies interaction-effects of construct x study profile were identified for the items *difficulty level, achievement,* and *fits me*. For these items we observed that among the STEM students, non-SCIENCE students' perceptions of their current science or technical study were more favourable than those of SCIENCE students, whereas among the non-STEM students, non-SCIENCE students' stereotypes of science or technical studies were less favourable than those of SCIENCE students with respect to these studies. That is, the effect of the measured construct on the score on the items varied with the study profile chosen by the student (i.e. SCIENCE or non-SCIENCE). Although these results are in line with our expectations (Hypothesis 5), only 6 of the 24 interaction-effects of construct x study profile were found. In addition, we observed one significant interaction-effect of construct x sex, namely for the item *difficulty level* of the technical studies. The effect of the measured construct on the score on the item varied with the sex of the students. We found that among STEM students, the girls' perceptions of the *difficulty level* of their technical study were more favourable than those of the boys, whereas among non-STEM students, the girls' stereotypes of the *difficulty level* of technical studies were less favourable than the boys' stereotypes of these studies. This result implies that except for the item *difficulty level* of technical studies, we have to reject Hypothesis 6.

Conclusions and discussion

The aim of the present study has been to assess whether stereotypical ideas about science-oriented studies in higher education correspond with reality, or more specifically, with the perceptions of students who actually enrolled in these studies. For adequate counselling purposes it is important to know the stereotypes of (sufficiently capable) students with respect to science-oriented studies and establish whether they are irrational. To this end, we first examined non-STEM students' ideas about and expectations (*stereotypes*) of science-oriented studies (the so-called STEM studies), that is of students who had not opted for such a study, but had chosen, for example, economics, law, or medicine. A distinction was made between stereotypes of science studies and of technical studies. Secondly, we investigated STEM students' experiences with (*perceptions of*) their chosen STEM study, in which we were particularly interested. We examined whether the perceptions of students who had opted for a science or technical study differed and whether the perceptions of students enrolled in a STEM study differed from those of students who had chosen a non-STEM study. Thirdly, we compared non-STEM students' stereotypes of STEM studies with STEM students' perceptions of STEM studies. Additionally, differences between suitably qualified students (i.e. SCIENCE students) and less qualified students (non-SCIENCE students) were examined as well as sex-differences.

We will first discuss non-STEM students' stereotypes of STEM studies. Our study reveals identifiable stereotypes of STEM studies with regard to achievement-related issues (e.g. expected difficulty level) and content-related issues (e.g. uninteresting). With respect to choice-related issues (e.g. specialization options) and the career perspectives of STEM studies the stereotypes are more favourable. Our results support Hypothesis 1 that non-STEM students' stereotypes of technical studies are more favourable than their stereotypes of science studies. Particularly, the career perspectives of science studies were viewed as less favourable than those of technical studies, as well as the expected narrow orientation of science studies (e.g less varied content, less options to choose from) as compared with the broader orientation of technical studies. In addition, science studies were expected to include more theoretical courses than technical studies. We found important differences between SCIENCE students and non-SCIENCE students with respect to their stereotypes of STEM studies. In general, SCIENCE students' stereotypes of STEM studies were more favourable than those of non-SCIENCE students regarding these studies, which supports Hypothesis 2. With respect to STEM studies we observed obvious differences in *expected difficulty level, expected achievement,* whether the study is *interesting,* but also whether a STEM study would *fit them*. This finding corresponds with the view that students partly choose their careers by matching their self-concept to their already established schematic representation of occupations (Lightbody & Durndell, 1996). Certain possible future perspectives are perceived as more plausible than other options because of the available role models in students' environment (Oyserman, Gant, & Ager, 1995). For the suitably qualified students (i.e. SCIENCE students) a STEM study would be suitable (or at least more so than for non-SCIENCE students). This result supports the expectation that a general interest and adequate performance in advanced mathematics, chemistry, and physics correlates with students' more favourable stereotypes of STEM studies. It illustrates that more experience with advanced mathematics, chemistry, and physics may lead to more positive stereotypes of science-oriented studies. On the other hand, it may also bring about less favourable attitudes, especially in the case of negative experiences, such as failure (Osborne, Simon, & Collins, 2003).

Furthermore, we expected that SCIENCE girls' stereotypes of STEM studies would be more favourable than those of SCIENCE boys, and that non-SCIENCE girls' stereotypes would be less favourable than those of non-SCIENCE boys (Hypothesis 3). We found several sex-differences for the stereotypes of technical studies and some very small interaction-effects between sex and SCIENCE/non-SCIENCE for the stereotypes of science studies. SCIENCE girls' stereotypes of the items *difficulty level*, *varied content, interesting*, *achievement*, *fits me*, and *different job opportunities* were in general more favourable than those of SCIENCE boys, whereas non-SCIENCE girls' stereotypes of science studies were less favourable than those of non-SCIENCE boys regarding these items. Only one significant interaction- effect was found between SCIENCE/non-SCIENCE and sex for students' stereotypes of technical studies, namely for the item *job useful for society*, indicating that SCIENCE girls' stereotypes of the usefulness of a technical study for society was more favourable than those of SCIENCE boys, whereas in the case of non-SCIENCE students, the stereotypes of the boys were more favourable than those of the girls. Hence, we found support for Hypothesis 3 for 6 of the 12 items concerning students' stereotypes of science studies, and for 1 of the 12 items concerning students' stereotypes of technical studies. The question why some SCIENCE girls did not choose a STEM study in higher education despite their (apparently) favourable attitudes requires further attention. For example, how do SCIENCE girls perceive their current study? The second part of this study has addressed this issue.

Here we have analyzed the perceptions of STEM students and non-STEM students of their chosen study. In general, the students' perceptions of their current study were, on average, positive and consistent across the items. Our exploratory analyses showed no substantial differences among the student groups (science, technical, or other students). We observed small differences among the three groups with respect to perceived difficulty level (with technical studies on top, followed by science studies), perceived contribution to general development (other studies were perceived to contribute the most), and perceived future perspectives (students opting for science or technical studies presume to have better future perspectives than students choosing other studies expect to have). This result indicates that in general the perceptions of STEM students of their current study did not deviate from the other students' perceptions of their current study, with a few minor exceptions as outlined above.

Thirdly, we examined to what extent non-STEM students' stereotypes of STEM studies differed from STEM students' perceptions of their study. In line with our assumption that students generally select the best suitable option when choosing a study (see Ajzen & Fishbein, 1980), science studies and technical studies were perceived more favourably by STEM students than stereotyped by non-STEM students (Hypothesis 4). An important result is that non-STEM students' expectations with respect to the content variety of science studies was less favourable than the perception of this item by students who actually opted for a science study (see also Fuller, 1991). Offering students detailed information concerning the broadness of science studies might change this stereotype. In addition, our results partly support the fifth hypothesis, indicating that among STEM students, non-SCIENCE students' perceptions of their current science or technical study were more favourable than those of SCIENCE students, whereas among non-STEM students, the non-SCIENCE students' stereotypes of science or technical studies were less favourable than those of SCIENCE students with respect to these studies. Our regression-analyses show that 6 of the 24 interaction-effects between construct (perception or stereotype) and study profile (SCIENCE or non-SCIENCE) on the students' item scores (e.g. perceived or stereotyped difficulty level) were significant. For both science studies and technical studies the interaction-effect was significant for the (expected or experienced) difficulty level. With respect to science studies it was also significant for the items *interesting* and *job useful for society*, and as regards technical studies for (expected or experienced) *achievement* and *fits me*. SCIENCE students' experience with math- and science-related topics in secondary education might have had a positive influence on their attitudes towards STEM studies, decreasing the differences between expectations and experiences. Non-SCIENCE students who chose a science or technical study in higher education might have changed their stereotypes during secondary education, for example as a result of changed future perspectives. Hence, these results suggest that early career advice prior to students' study profile choice can help students choose the best preparatory profile for their desired future career.

Finally, we had to reject Hypothesis 6 because we only found one significant interaction-effect of construct x sex on the students' item scores. The invalidness of this hypothesis indicates that the differences between stereotypes and perceptions of STEM studies are practically the same between the sexes in our sample. These differences may have been slightly larger for girls than for boys for some items, but no systematic sex-difference appeared in the regression-analyses. Only for the difficulty level item did we find that among the STEM students the girls' perceptions of the difficulty level of their current technical study were more favourable than those of the boys, whereas among the non-STEM students, the girls' stereotypes of the difficulty level of technical studies were less favourable than those of the boys. Lightbody and Siann (1997) suggest that although women tend to avoid STEM studies, this is not a negative choice. Women generally prefer courses which prepare them for more social-oriented careers (see also Lips, 1992). This might explain why the differences we found between stereotypes and perceptions were, in general, not larger for girls than for boys.

There are a number of limitations to consider when interpreting and generalizing the present findings. Generalization of the present data is restricted because our sample represents only 32% of all respondents approached. Moreover, girls are largely overrepresented in the sample (65%). However, with respect to students' study profile choice it is representative of the Dutch student population, that is, 30% of the boys and 3% of the girls took their FSE in the SCIENCE study profile. A second limitation is that we had no information on STEM students' stereotypes of STEM studies during the time they attended secondary education. A longitudinal study in this field would strengthen our results, because then we could analyze how students' attitudes evolve over time before they eventually result in a final study choice (STEM or non-STEM). Thirdly, we propose a more qualitative approach to unravel the stereotypes of SCIENCE girls in more detail. Notwithstanding their relatively favourable attitudes towards STEM studies, they did not pursue a science-oriented career when entering higher education. In future research the origin of this sex-effect should be investigated as well as its development from primary education onwards. In-depth interviews could, for example, bring to light why some students reported that science-oriented studies would not fit them.

Despite these limitations, this study addresses important issues for educational practice. Since systematic differences between stereotypes and perceptions exist, our results can be used by counsellors to improve their guidance and advice accordingly. In other words, the present study provides essential knowledge about those topics that need further attention in career guidance, for example the content of science studies and the difficulty level of STEM studies in general. Packard and Nguyen (2003) report that girls who participated in intensive math and science programmes during secondary education, indicated that mentoring and career-related internships helped them think about the suitability of a science-oriented career. Several initiatives are developed in the Netherlands, for example female role models are invited to the schools to talk with the students about their daily work. We also believe that students' expectations of whether STEM studies would fit them needs further attention in STEM campaigns. With respect to the issue of making educational choices future studies should consider the consequences of the fit between students (e.g suitably qualified girls) and the environment (e.g. STEM studies) (e.g. Holland, 1997). The differences we observed between SCIENCE and non-SCIENCE students highlight the effect of early selection in secondary education. More experience with math- and science-related topics could result in more favourable attitudes towards STEM and, consequently, in an increased STEM entry. Once students have chosen a non-SCIENCE study profile at the end of the 9^{th} grade, they are no longer eligible for STEM studies; at least not without supplementary entry-exams.

In conclusion, the current study presents a unique comparison between students' stereotypes and "actual reality". We found both small and large differences between the stereotypes and perceptions of science-oriented studies. This study contributes to the research literature on students' attitudes towards STEM studies in higher education, building on the already existing knowledge about students' attitudes towards mathematics and science in secondary education. It adds useful insights in view of the growing interest of researchers in the impact of early selection in secondary education (i.e. in our case the study profile choice), as early selection has a large impact on STEM-entry.

Chapter 7

Students Leaving the STEM Pipeline; An Investigation of their Attitudes and the Influence of Significant Others on their Study Choice*

Abstract

The main aim of the present study was to find an answer to the question why some suitably qualified students do not continue their education in science-oriented studies in higher education, despite their previous interest in science-related topics in secondary education. The research was based on the multi-attribute utility theory, using an approach related to the theory of reasoned action (Fishbein & Ajzen, 2010). The study included 477 students who had taken basic or advanced math/science courses in secondary education, but who did not choose a STEM study in higher education (STEM stands for science, technology, engineering, and mathematics). The attitudes of these students towards STEM studies were compared with their attitudes towards their current (non-STEM) study, while also taking the influence of significant others on these students' study choices into account. As expected, most non-STEM students had chosen the best "suitable" option as regards their attitudes. However, one out of ten non-STEM students had a more favourable attitude towards STEM studies than towards their current study. Particularly girls who had taken advanced math/science courses in secondary education belonged to this group. However, the hypothesis that these students had left the STEM pipeline because of the advice of significant others was not confirmed.

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Introduction

Choosing a study in higher education is an important decision in the light of a student's future career. We therefore expected that this choice is a fairly rational one. Within the field of psychology, behavioural decision theory (e.g. Fishbein & Ajzen, 2010) is often used to investigate these kinds of choice processes. According to this theory, students are expected to recognize and involve the importance and consequences of educational choices in their decision process and choose the best suitable option. Students' study choice, for example, is expected to be in line with their abilities, interests, and future perspectives. The assumption of behavioural decision theory is that people are usually quite rational and that they use the information available to them in a systematic manner when making decisions. For example, people make use of their earlier experiences to weigh up the pros and cons of their options. Did they like it in the past? How did it go last time? Furthermore, it is assumed that people take the implications of their behaviour into consideration when making decisions. For instance, people may speculate upon what will happen once their choice has been made. Which outcome do they prefer? At some occasions however, people diverge from making rational choices, particularly when the information available to them is not complete (Feather, 1982; Kahneman & Tversky, 2000). These are usually situations in which it is impossible to make a full assessment of the situation due to uncertainty about the consequences of certain behaviour (Van Schie, 1993). Study choice in higher education is such a situation. Students may have some experience with certain school subjects as well as some general notions about what to expect from a particular study, but the information they have is usually incomplete. Moreover, the consequences of this choice are largely uncertain. It is, for example, uncertain whether the student will successfully complete the study or whether he/she will either like or dislike its content (Van den Brink, 1993).

The present study has investigated students' attitudes towards particular studies in higher education. More specifically, it has focussed on students eligible[1] for STEM studies (science, technology, engineering, and mathematics) who did not enter such a study in higher education. We will refer to this group as "non-STEM students" from this point onwards. Our main interest is why these suitably qualified students did not continue their education in STEM, notwithstanding their previous interest in science-related topics (i.e. they chose a science-oriented set of school subjects in secondary education). The attitude towards mathematics and/or science has been found to be a significant predictor of students' enrolment (or intentions to enrol) in math/science classes (e.g. Osborne, Simon,

[1] Students are eligible when they take their Final School Examinations (FSE) in advanced mathematics, chemistry, and physics at the end of Dutch secondary education.

& Collins, 2003) and STEM studies (e.g. Fuller, 1991; Second Phase Advisory Point, 2005; Verhorst & Verhulst, 1993; Warps, 2001).

Since at the time of our research our participants had already made their study choice (see also Chapter 6), we have not attempted to explain or predict this decision (e.g. by searching for determinants of students' study choice). Instead, we set two primary objectives. First, we looked into non-STEM students' attitudes towards STEM as compared to their attitudes towards their actually chosen study to find out whether they had opted for the best suitable option as regards their attitudes. Based on the principles of behavioural decision theory, among STEM students we expected more favourable attitudes towards the studies chosen than towards the STEM studies (e.g. Fishbein & Ajzen, 2010). Since the STEM discipline is quite broad, we made a distinction between science studies (e.g. mathematics, physics, chemistry) and technical studies (e.g. industrial engineering, architectural engineering, electrical engineering) throughout our research. Second, we searched for the characteristics of students who had chosen a less suitable option as regards their attitudes. We examined whether it concerned mainly boys or girls and whether these students had followed basic or advanced math/science courses in secondary education (see the method section for further details). In addition, we investigated the influence of significant others (e.g. parents, teachers, and peers) on these students' study choices. Students make career choices within the context of parental expectations (e.g. Maple & Stage, 1991) and socialization through peers (e.g. Leslie, McClure, & Oaxaca, 1998). Parents shape students' beliefs about gender-typed occupations and consequently influence students' career decisions (Chhin, Bleeker, & Jacobs, 2008). Students are often unaware of this influence on their decisions. Finally, we studied the underlying structure of these students' attitudes to identify what "caused" their decision to leave the STEM pipeline despite their ability and favourable attitude towards STEM studies. A description of our expectations (hypotheses) regarding these objectives is presented subsequent to the theoretical framework. The theoretical framework section gives a short introduction to the behavioural decision theory on which we based our research. In addition, it presents some theoretical concepts we used from the theory of reasoned action (Ajzen & Fishbein, 1980) to build our attitude construct from several components. Subsequently, we will outline how we applied these insights to the approach we used in the present study.

Theoretical framework

Behavioural decision theory

This section discusses some basic ideas from the behavioural decision theory. Two main approaches are important here, although the distinction is not entirely strict: the rational or normative decision theory and the descriptive decision theory. The rational or normative decision theory prescribes how people should make (rational-analytic) optimal judgements or decisions in specific contexts (e.g. in gambling games and daily life situations). The theory also provides tools for making people's decisions more rational, for example, by changing their often incorrect assessments of chance. The descriptive approach focusses more on the explanation of why people have a tendency to make non-rational choices. Studies in this field usually attempt to explain discrepancies between optimum (i.e. rational) and observed behaviour. They use descriptive models to describe and explain processes of human judgement and decisions in order to understand how these processes work in reality. These studies search for determinants of judgements or decisions, for example the impact of motivation on students' educational choices (Koele & Van der Pligt, 1993).

It is assumed that behaviour is related to one's expectations and subjective valuation of the consequences of a certain behaviour. Multi-attribute theory (e.g. MAUT [multi-attribute utility theory]; e.g. Keeney & Raiffa, 1993) and expectancy-value theory (e.g. SEU [subjective expected utility]; Edwards, 1961; Feather, 1982) are based on this assumption. The utility concept refers to a person's preferences; it is a generalized measure of desirability (Feather, 1982). MAUT is a multi-criterion decision making (MCDM) technique based on the utility theory (for an overview of MCDM methods, see: Triantaphyllou, 2000). Multi-attribute utility (MAU) models are mathematical tools for evaluating and comparing alternatives in decision making (prescriptive) or can be used to describe why different people make different choices (descriptive). They seek to answer the question "What is the best alternative?" In MAU models, each attribute is given an importance weight (e.g. the difficulty level of a study, or the importance of future job perspectives). The score of each alternative (e.g. a STEM study) is based on "how well it performs" for each attribute. These scores are weighed by the relative importance of the attribute and then added up to provide an overall multi-attribute score for each option. The option with the highest total score is the one to be chosen. Thus, the models are based on the assumption that the desirability of an alternative depends on how its attributes are evaluated, particularly, the subjectively most important attributes. Similar constructs are used in SEU. This is a normative theory of decision-making in *uncertainty*, which specifies how decisions should be made. The expectancy-value approach to decision making refers to the situation where people weigh the subjective probabilities with the subjective values associated with the available options, and that they choose the one with the maximum utility subjectively expected. Subjective probability refers to the probability that the expected consequence of a choice (e.g. choosing math) will actually occur (e.g. "I expect to fail when I choose math"), multiplied by a person's subjective value (e.g. "How much does it matter to me when I fail math?").

Judgements and decisions in daily life are, however, scarcely made on the basis of formal decision models (Van Schie, 1993). The inconsistency between actual decision behaviour and normative models shows that people do not reason statistically. People tend to use general heuristics (i.e. rules of thumb) to evaluate and combine complex information in making decisions (Kahneman, Slovic, & Tversky, 1982). Probability assessments are to some extent subjective, and can therefore be biased and non-rational. Kahneman and Tversky (2000) suggest that people employ simplistic rules of thumb to reduce complex information to a manageable size, which can consequently cause misrepresentations of this information. Interestingly, when people deviate from rational choices, these departures are usually systematic (Kahneman & Tversky, 1972). For example, people tend to pay more attention to information that confirms their beliefs than to contradictory information (i.e. confirmation bias; Hamilton, 1981; Van Schie, 1993). Moreover, also motivational factors can influence people's decisions. Some people, for example, show risk-avoiding behaviour (and thus choose the safest option), or they let their decisions be influenced by others because they want to fit into a particular social group (e.g. Janis & Mann, 1977).

It is beyond the scope of this chapter to discuss the models mentioned in the previous paragraphs in detail. Instead, we will focus on one specific theory related to MAUT and SEU, which is the theory of reasoned action (TRA) of Ajzen and Fishbein (1980) presented in the next section. TRA is also based on the basic principles of behavioural decision theory, that is, the assumptions that people are usually quite rational and make systematic use of the information available to them, and that they take the implications of their behaviour into consideration when making decisions (Ajzen & Fishbein, 1980). This theory is often used to predict (or explain) people's intentions to act in a certain way.

The theory of reasoned action

TRA (Fishbein & Ajzen, 2010) states that attitudes towards certain behaviour are the result of balancing all advantages and disadvantages associated with this behaviour. Attitudes can be defined as mental concepts that depict either favourable or unfavourable feelings towards an object (Koballa, 1988), for example "I like mathematics" or "I enjoy mathematics". A similar approach concerning the definition of attitudes towards science is presented by Gardner (1975, p. 2), who defines attitude as "a learned predisposition to evaluate in certain ways objects, people, actions, situations, or propositions involved in learning science". Attitudes are found to be well predictive of behavioural intentions, for example the intention of students to enrol in science courses (e.g. Sullins, Hernandez, Fuller, & Tashiro, 1995). Based on their TRA theory, Ajzen and Fishbein (1980) developed an attitude-behaviour model to predict behavioural intentions (see also Fishbein & Ajzen, 1975; Ajzen & Madden, 1986). According to their approach, the formation of attitudes depends on the expectancy-value model mentioned in the previous paragraph (Fishbein & Ajzen, 2010). The conceptual framework of Ajzen and Fishbein (1980) emphasizes the necessity of distinguishing between beliefs, attitudes, intentions, and behaviour (see Figure 1).

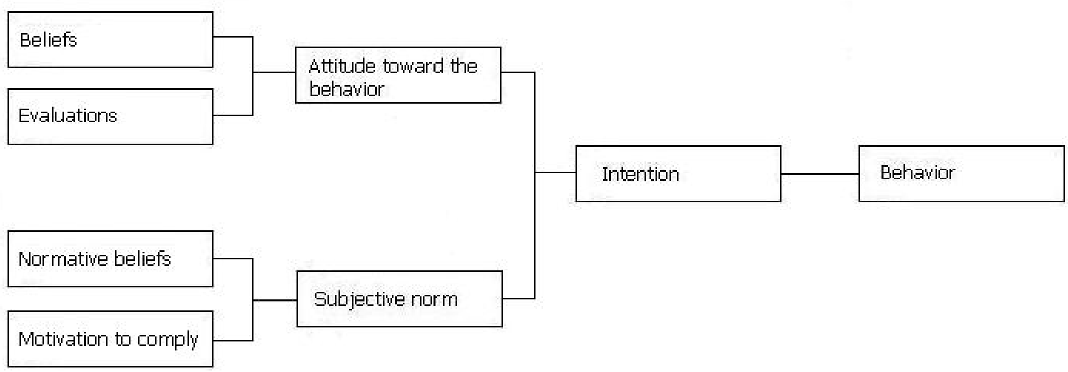

Figure 1. Theory of reasoned action (Ajzen & Fishbein, 1980)

This theory assumes a causal chain linking beliefs, formed on the basis of available information, to a person's attitudes, and attitudes to intentions, and intentions to behaviour. The causal chain starts all over again when the person's behaviour provides him/her with new information that influences his/her beliefs. Since attitudes cannot be observed directly, the constructs in the model are built from several components. TRA suggests that a person's behavioural intention depends on his/her attitude about certain behaviour and his/her subjective norms. Hence, both components consist of two parts. The attitude consists of beliefs about the consequences of the behaviour (e.g. "I need to work hard to do well in math" [not at all - very much]) multiplied by a persons' valuation of these consequences (e.g. "Doing well in math makes me [not at all - very] happy"). All belief strength x evaluation products are added up to produce an overall expectancy-value index (Fishbein & Ajzen, 2010). The subjective norm (i.e. social influence) consists of perceived expectations regarding significant individuals or groups (i.e. normative beliefs; e.g. "My parents think that I should choose advanced mathematics" [not at all - very much]) and a persons' intention to comply with these expectations (e.g. "How much do you care what your parents think you should do?" [not at all - very much]). Combined together, this means that if people evaluate certain behaviour as positive and want to comply with significant others who want them to exhibit this behaviour, their intention to do so will be stronger than when their attitude is less favourable and/or when they perceive the social influence as weaker (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). Similarly, the opposite is also applicable. If students evaluate the choice of math/science courses as a negative one (e.g. due to the negative image of nerds engaged in science) and/or think that significant others (e.g. peers, parents) will disapprove of choosing math/science courses, their intention to do so will be less strong. Background factors such as sex, ethnicity, intelligence, and personality are assumed to influence intentions and behaviour indirectly by affecting one or more components in the model, for example (some of the) behavioural beliefs. That is, the attitude and subjective norm component are assumed to mediate the effects of these factors on intentions and behaviour (Ajzen & Fishbein, 1980).

Since having the intention to behave in a certain way does not necessarily mean actually doing so, Ajzen (1985, 1991) extended TRA to the theory of planned behaviour (TPB) by adding a new component, namely perceived behavioural control. This concept is similar to the self-efficacy construct (Bandura, 1986; Ajzen, 2002). The adjustment was necessary because TRA could not deal with behaviour over which people do not have sufficient volitional control. The self-efficacy construct refers to a person's self-perception of his/her ability, which means a person's perceived ease or difficulty with which he/she can initiate particular behaviour. It is linked to control beliefs, referring to people's beliefs about the occurrence of factors that may facilitate or impede certain behaviour (Ajzen, 2002). Perceived behavioural control is usually measured through a self-report instrument by which students rate the extent to which they have the ability to perform the behaviour with items such as "I am sure I can pass this math test". The extended theory was found to be well supported by empirical evidence (Ajzen, 1991). Meta-analyses of empirical studies have provided evidence that intentions can be predicted with considerable accuracy by means of TPB (Armitage & Conner, 2001). Accordingly, the prediction whether a person will behave in a certain way is based on their intention to do so as well as on their perceived behavioural control of performing these planned actions. TRA and TPB are applicable in many contexts (Fishbein & Ajzen, 2010). Examples of studies in which these theories are used in an educational choice context are those of Butler (1999), Dalgety, Coll, and Jones (2003), Otten and Kuyper (1988), Stead (1985), and Van Heugten (1993). The current state of the theory can be found in Fishbein and Ajzen (2010), where they stress the importance of actual control (e.g. relevant skills and abilities) in addition to perceived behavioural control to predict human behaviour. Further, they added descriptive normative beliefs to their model in addition to the "injunctive" normative beliefs in the original version. Descriptive normative beliefs refer to a person's belief that other people will actually perform certain behaviour (e.g. "I think other people will display the particular behaviour" [not at all - very much]).

An important difference between MAUT and TRA is the way in which the attributes are specified. TRA is more researcher-driven than MAUT because the attributes ("beliefs and evaluations" in TRA) that could predict intentions are pre-specified by the researcher. MAU models on the other hand, are designed to help decision makers structure their own, individual, decision problems. Whereas MAUT focusses on a decision problem of one person, TRA is a more general theory that attempts to explain differences among individuals in their intentions to exhibit particular behaviour (e.g. stop smoking). Our study is based on MAUT because we evaluated several alternatives (i.e. search for the best option) for each individual. However, our *approach* was more in line with TRA because we specified the model beforehand.

The present study

As stated in the introduction, this study has concentrated on students who were eligible for STEM based on their prior education, but who did not enter a STEM study in higher education (non-STEM students). These students took their FSE in advanced mathematics, chemistry, and physics in secondary education, thereby demonstrating that they were sufficiently capable of entering a STEM study. Our main aim has been to try to answer the question why these suitably qualified students did not continue their education in STEM, despite their previous interest in science-related topics. To this end we have focussed on their attitudes towards particular studies (e.g. Fuller, 1991; Second Phase Advisory Point, 2005; Verhorst & Verhulst, 1993; Warps, 2001), namely the study they actually opted for, science studies (e.g. mathematics, physics, and chemistry), and technical studies (e.g. industrial engineering, architectural engineering, and electrical engineering). Following MAUT, we evaluated the three alternatives (i.e. chosen, science, technical) for each individual. In this paragraph we give an outline of our TRA-based approach to evaluating the three alternatives and finding each student's "optimal" choice. Figure 2 graphically presents the model used in our study.

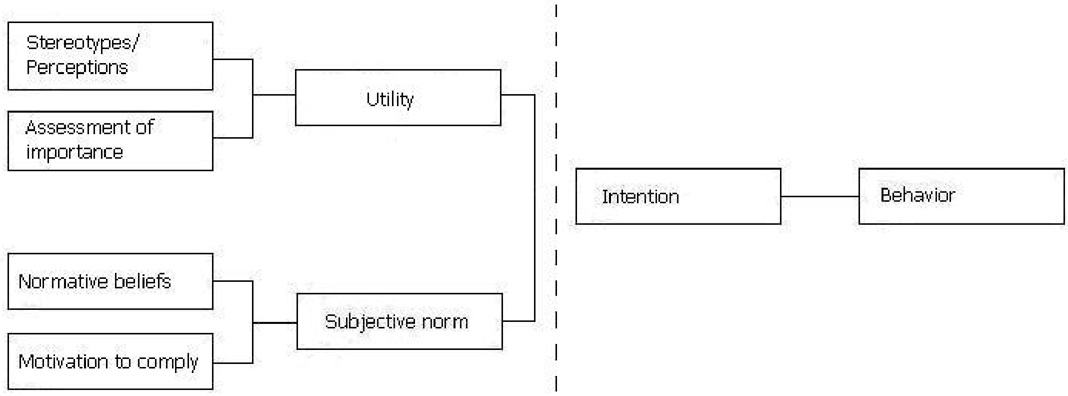

Figure 2. The model used in the present study

The original TRA model (similar to TPB) consists of the beliefs and the evaluations of these beliefs to build the construct "attitude". Our approach included the constructs *perceptions* and *stereotypes* instead of *beliefs* and *assessment of importance* instead of *evaluation*, because we wanted to assess students' attitudes towards the several alternatives out of which they had actually chosen one (i.e. the chosen study vs. science and technical studies). The beliefs of non-STEM students about their current study are based on their *perceptions* (e.g. "I think my current study is [very easy - very difficult]"). Students' beliefs about STEM studies are based on more general notions or expectations, for example on the expected difficulty level (e.g. "I think a technical study is [very easy - very difficult]"). For a clear distinction between the two types of beliefs we refer to *stereotypes* when we talk about non-

STEM students' beliefs about STEM and to *perceptions* when we refer to their beliefs about the actual study of their choice. We used *assessment of importance* to measure students' valuation of the consequences of certain behaviour (e.g. "I find the difficulty level of a study [not at all important - very important]"). *Assessment of importance* showed which stereotypes and perceptions were salient. Hence, when referring to the constructed score we use the concept *utility* (U) rather than *attitude* because of the differences in the evaluation measurement (i.e. *assessment of importance*) as compared to the original TRA/TPB model. Finally, students' intentions and resulting behaviour have not been included because our participants had already chosen a study (their study choice represents their established preference). This is depicted in Figure 2 by the dotted line. Additional information on the measurement of the items and components in these models can be found in the Method section.

Hypotheses. As stated in the introduction, based on their subjective expectation people are assumed to choose the alternative with the highest subjectively expected utility (e.g. Feather, 1982). Therefore, we expected that students' utility score of their chosen study (Uc) would be higher (more favourable) than that of the alternatives, in our case, STEM studies (i.e. Us [utility score science studies] and Ut [utility score technical studies]). In addition, we compared the students' utility scores on science studies with their utility scores on technical studies to find out which of the two alternatives had the highest subjectively expected utility. We presumed that students' utility score on technical studies (Ut) would be generally higher than their utility score on science studies (Us), because in the Netherlands more students enter technical studies than science studies[2] (Statistics Netherlands, 2010). Based on these expectations we present our first two hypotheses:

Hypothesis 1: Non-STEM students' utility score on their chosen study is higher than their utility score on STEM studies (i.e. Uc > Us and Uc > Ut).

Hypothesis 2: Non-STEM students' utility score on technical studies is higher than their utility score on science studies (i.e. Ut > Us).

In addition, we investigated two groups of non-STEM students in more detail. These were students who had higher utility scores on science and/or technical studies than on their study actually chosen (i.e. they would fit a STEM study) and students who had more or less comparable utility scores on the three alternatives (i.e. they would fit a STEM study equally well as their current study). We refer to these groups as "STEM candidates" and "possible STEM candidates". We compared these groups with the other non-STEM students (the

[2] In 2007/2008, 6% of the overall group of first year students in higher education entered a science study whereas 9% of this group entered a technical study (Statistics Netherlands, 2010).

students with the highest utility score on their chosen study (referred to as "no STEM candidates") to investigate whether in these groups they were mainly boys or girls and whether they were students who had taken the FSE in basic or advanced math/science courses[3]. It can be argued that rather than boys and/or students who have taken the basic courses in secondary education, STEM candidates are primarily girls who have taken advanced courses in secondary education. Girls more often regret their decisions (e.g. school subject choices) in hindsight than boys do (Kuyper & Otten, 1989), and students who have taken the advanced courses are assumed to be particularly interested in math/science-related topics (see also Chapter 2 of this dissertation). However, the theoretical basis for this line of reasoning is limited, which is why we did not formulate any hypotheses regarding these issues. Exploratory analyses are included in the results section. Second, we investigated the influence of significant others on the students' study choice (in TRA/TPB: the *subjective norm* component). More specifically, we examined whether non-STEM students who chose a less suitable option[4] (STEM candidates) were more strongly influenced by significant others to choose a non-STEM study than non-STEM students who chose a (more) suitable option[5] (possible STEM and no STEM candidates). For instance, these students might have chosen a study following their parents' advice. Based on the previous findings (e.g. Chhin et al., 2008; Leslie et al., 1998; Maple & Stage, 1991), we expected that:

Hypothesis 3: Non-STEM students with higher utility scores on STEM studies than on their chosen study (Us > Uc and/or Ut > Uc) will have higher scores on the subjective norm component as regards choosing a non-STEM study than other non-STEM students.

Third, we examined the underlying structure of students' utility scores to discover which perceptions and stereotypes of students who had chosen a less suitable option (STEM candidates) deviated from those of other non-STEM students (possible STEM and no STEM candidates). Similarly, we explored the importance the students ascribed to the attributes listed (e.g. the difficulty level of a study) and their actual study choice. Finally, we investigated these students' actual study choices to understand which disciplines they had preferred to STEM studies. Exploratory analyses concerning these issues are included at the end of this chapter.

[3] See method section for more information regarding the distinction between basic and advanced math/science courses.

[4] These are the students who have higher utility scores on STEM studies than on their chosen study.

[5] These are the students who have higher utility scores on their chosen study than on STEM studies.

Method

Participants

Information regarding the design of the study, the data collection, and the sample can be found in Chapter 6. For this study, we selected students from the overall 1,935 participants in the previous study on the basis of two additional criteria. First, we selected students that had chosen a non-STEM study in higher education (e.g. medicine, law, economics; 1,629 students). Within this group, we selected students who had completed the FSE in advanced mathematics, chemistry, and physics (SCIENCE and HEALTH students[6]) and thereby met the criteria for entering a STEM study in higher education[7]. These students were therefore eligible for STEM studies, but had chosen a non-STEM study. This procedure resulted in a sample of 477 students of which 16 were SCIENCE girls, 41 SCIENCE boys, 324 HEALTH girls, and 96 HEALTH boys.

Variables and instruments

Stereotypes. A questionnaire was used to measure the students' stereotypes of science-oriented studies. To measure these stereotypes twelve items were used which in previous research were found to be important issues for students when making educational choices. The answer categories ran from 1 to 7 (e.g. from *very few* to *very much*). The students were asked whether they expected science-oriented studies to be: (1) difficult or easy (e.g. "I think a technical study is [very easy - very difficult]") (2), narrowly focussed or broadly oriented, (3) uninteresting or interesting, (4) including few or many theoretical courses, (5) including few or many options to specialize, (6) including few or many additional choice options, (7) a study in which they would achieve well, (8) contributing to their development in general, (9) generally suitable ("fits me"), (10) offering good opportunities to find an attractive job within six months after their graduation, (11) preparing them for a useful job in society, and (12) preparing them for a few or many different job opportunities. The students had to answer these questions for both the science studies and the technical studies. For 6 students some of the science study item scores were not available (<1% non-response), while this was the case for 15 students with respect to some of the technical study items (1% non-response).

Perceptions. The students' perceptions of their current study were measured by using items matched with the 12 items listed in the previous paragraph (e.g. "Do you find your

[6] More information regarding the study profiles can be found in Chapter 6.

[7] HEALTH students are eligible with additional requirements only (i.e. these students have to take advanced physics courses instead of basic courses in secondary education).

study difficult or easy?"), again with answer categories running from 1 to 7. For 6 students some of the item scores were not available (<1% non-response).

Assessment of importance. For each of the 12 items the students had to indicate to what extent they found them important, for example: "I find the difficulty level of a study [not at all important - very important]"). The answer categories ran from 1 to 7 (from *not at all important* to *very important*).

Motivation to comply. The students were asked whether their study choice was influenced by someone (yes or no). If so, they had to answer two additional questions. They were asked by whom they were influenced and to what extent each of these people had influenced them (on a scale from 1 to 7, from *not at all* to *very much*). They could select six options, namely their parents/guardians, their friends, their partner, people from school (e.g. their dean, tutor, or particular teachers), an older brother or sister, or someone else.

Normative beliefs. The students who responded that their study choice was influenced by someone (see *motivation to comply*) had to indicate what these people's recommendations were (*injunctive normative beliefs*; Fishbein & Ajzen, 2010). We asked whether these people had advised the student to choose the study he/she had actually chosen, a science study (e.g. mathematics, physics, or chemistry), a technical study (e.g. industrial engineering, architectural engineering, or electrical engineering), a medical study (e.g. medical science, nursing, or physiotherapy), an economical study (e.g. economics, business administration, or marketing), or another study. For all 6 options the answer categories ran from 1 to 7 (from *not at all* to *very much*).

Procedure

Utility. The utility scores were constructed as a weighed result of the scores on the stereotypes/perceptions items and the assessment of importance items. First, the answers with respect to the stereotype and perception items were recoded to bipolar items. Beliefs with bipolar scoring (ranging from -3 to +3) and assessment of importance (or evaluations) with unipolar scoring (ranging from 1 to 7) is theoretically the most appropriate scoring combination (O'Keefe, 2002). This was possible for 464 students (97%). For 3% of the cases this was not possible due to item non-response. The responses to both components of the utility construct were multiplied to provide a range of values (from -21 to +21), whereby negative values referred to unfavourable stereotypes/perceptions and positive values to favourable stereotypes/perceptions. For example, a student who scored -2 on the stereotypes item *difficulty level of technical studies* and 3 on the corresponding assessment of importance item obtained -6 for this component. The sum of the 12 component scores represented the students' utility score (on their chosen study [Uc], on science studies [Us], and on technical studies [Ut] respectively). Theoretically, the utility scores range from -252 to +252. In our sample, they ranged from -33 to 187 (Uc), -155 to 244 (Us), and -127 to 210 (Ut).

Subjective norm. The subjective norm was measured as a weighed result of *normative beliefs* (6 items each ranging from 1 to 7) and *motivation to comply*. In our sample, the scores on *motivation to comply* ranged from 7 to 31 with an average of 16. Instead of the total scores, the highest score on one item was used to measure this item, because we considered it plausible that once, for instance, parents had largely influenced a student, it became irrelevant that he/she had also been influenced, either to a smaller or lesser extent, by – for example – peers. This procedure resulted in six subjective norm scores, which ranged from 1 (1 x 1) to 49 (7 x 7). For example, if a student's score on normative beliefs with respect to choosing a technical study was 4, and the highest score on motivation to comply (e.g. to his/her parents) 3, then his/her score on the subjective norm as regards technical studies would be 12 (4 x 3).

Results

The utility component

Table 1 shows the descriptive results for the 12 stereotype/perception items. The means and standard deviations (between brackets) of each item are presented for non-STEM students' perceptions of their chosen study, their stereotypes of science studies and technical studies, and their assessment of the importance of the items. In addition, the means and standard deviations of the three computed utility scores are included in the three rightmost columns of the table.

The items' mean scores presented in the first three columns of Table 1 show that the students' perception scores on their chosen study are visibly more favourable than their stereotype scores on science-oriented studies for the items *varied content*, *interesting*, *general development*, and *job useful for society*. The future perspectives of technical studies (*job within six months* and *different job opportunities*) and their choice-related perspectives (*specialization options* and *options to choose*) correspond with the students' perceptions of their chosen study, whereas their stereotypes of science studies are less favourable with respect to these items. These results are generally in line with our expectations. The fourth column of the table shows that, on average, all 12 items are evaluated as important when choosing a study in higher education. The highest scores on *assessment of importance* are found for the items *interesting, fits me*, and *varied content*. The *difficulty level* of studies is evaluated as the least important item.

Table 1 *Item scores and utility scores for non-STEM students (means and standard deviations)*

	Perceptions chosen study[a]	Stereotypes science studies[a]	Stereotypes tech. studies[a]	Assessment of importance[b]	Utility chosen study[c]	Utility science studies[c]	Utility tech. studies[c]
Difficulty level	-0.2 (1.2)	-1.3 (1.2)	-1.5 (1.1)	4.2 (1.2)	-0.9 (5.5)	-5.6 (5.4)	-6.5 (5.5)
varied content	1.5 (1.1)	-0.5 (1.4)	0.2 (1.3)	5.7 (0.9)	8.9 (6.8)	-3.1 (8.1)	0.9 (7.9)
Interesting	1.9 (0.9)	-0.1 (1.6)	-0.4 (1.6)	6.3 (0.8)	12.5 (6.4)	-0.8 (10.3)	-2.6 (10.2)
theoretical courses	0.9 (1.3)	1.8 (1.1)	0.9 (1.3)	4.5 (1.2)	4.2 (6.5)	8.1 (5.4)	3.9 (6.1)
specialization options	1.2 (1.5)	0.5 (1.5)	1.2 (1.1)	5.0 (1.3)	6.7 (8.3)	2.4 (7.8)	5.8 (6.1)
options to choose	0.6 (1.5)	0.0 (1.3)	0.8 (1.2)	4.9 (1.2)	3.8 (8.0)	0.2 (6.7)	3.9 (5.9)
Achievement	1.1 (0.8)	-1.2 (1.4)	-0.6 (1.4)	5.3 (1.1)	6.3 (5.1)	-0.9 (8.0)	-3.2 (7.9)
general development	1.6 (1.1)	-0.1 (1.3)	0.2 (1.2)	5.2 (1.2)	8.9 (6.6)	-0.6 (7.4)	1.0 (6.8)
fits me	1.8 (1.0)	-0.6 (1.5)	-1.0 (1.5)	6.2 (0.8)	11.6 (6.8)	-3.8 (9.8)	-6.3 (9.4)
job within half a year	1.1 (1.4)	0.5 (1.3)	1.2 (1.7)	5.2 (1.3)	6.4 (7.7)	2.8 (7.4)	6.0 (6.6)
job useful for society	2.0 (1.1)	0.3 (1.3)	0.9 (1.1)	5.2 (1.4)	11.2 (6.6)	1.6 (7.2)	4.8 (6.2)
Different job opportunities	1.1 (1.5)	0.2 (1.3)	1.0 (1.1)	5.0 (1.3)	6.6 (8.0)	1.0 (7.0)	5.1 (6.1)
Overall mean[d]					86.1 (37.8)	1.7 (51.9)	13.0 (45.7)

Notes. [a] The scores range from -3 to +3; [b] The scores range from 1 to 7; [c] The scores range from -21 to + 21; [d] Sum of the 12 mean scores.

The three rightmost columns of Table 1 show the constructed utility scores for all items. As some of the items' mean scores are negative, so are some of the utility scores (i.e. unfavourable). Finally, the lower row shows the overall mean scores on the utility variables. We found that, in general, students' utility score on their chosen study was higher than their utility score on STEM studies and that, on average, their utility score on technical studies was slightly higher than their utility score on science studies.

Test results Hypothesis 1 and 2

To test statistically whether the non-STEM students' utility score on their chosen study was higher than their utility score on STEM studies (Hypothesis 1), we used paired samples t-tests (one-tailed) for the overall mean utility scores (a within person comparison). The results show that the students' utility scores on their chosen study were significantly higher than their utility scores on science studies (t = 28.78, df 470, $p < .001$) and also higher than their utility scores on technical studies (t = 28.20, df 464, $p < .001$). The effect sizes (Cohen's d) are respectively 1.86 and 1.75, which is extremely large. We also used a paired samples t-test for Hypothesis 2 (Ut > Us). Again, the difference we found was significant (t = -5.00, df 463, $p < .001$), with an effect size of 0.22. The students' utility scores on technical studies were significantly higher than their utility scores on science studies. Hence, we found support for the first two hypotheses.

Defining three subgroups

We searched for common characteristics of the students for whom the utility score on the chosen study was lower than that on science and/or technical studies. To define a category of students who had preferred a less suitable option to a better suitable alternative we calculated discrepancy scores between each pair of utility scores. This approach resulted in two discrepancy scores for each student:

- Discrepancy score A: Uc minus Us
- Discrepancy score B: Uc minus Ut

In this way we could establish whether the non-STEM students' utility scores on their chosen study were higher than their utility scores on science or technical studies. Positive discrepancy scores are associated with a higher utility score on the chosen study than on science or technical studies, whereas negative discrepancy scores stand for a higher utility score on science or technical studies than on the study actually chosen. Evidently, the utility scores can also be equal, which means that they are equally favourable.

Although for most students the discrepancy scores were positive, 52 students (11%) had negative scores; 34 (7%) for discrepancy score A and 36 (8%) for discrepancy score B, which means that there was an overlap of 18 students. Moreover, a considerable group showed only small differences in the utility scores. We used the criterion of a maximum of

half a standard deviation (SD) above 0 (≈ equal utility scores). The standard deviations (SD) were 64 for discrepancy score A and 56 for discrepancy score B. In total, 79 students showed these small differences in the utility scores. From this group, 18 students had scores within this range for both discrepancy scores A and B. The other 61 students had these scores for either discrepancy score A or B. Hence, for further analyses, we used three subgroups of students:
(1) STEM candidates: students with one or two negative discrepancy scores;
(2) Possible STEM candidates: students with a positive discrepancy score A between 0 and 32 (1/2 SD) and/or a positive discrepancy score B between 0 and 28 (1/2 SD);
(3) No STEM candidates: students with a positive discrepancy score A higher than 32 and a positive discrepancy score B higher than 28.
Thus, students in the STEM candidates group had higher utility scores on science and/or technical studies than on their chosen study (Us > Uc and/or Ut > Uc) and therefore they would fit a science and/or technical study in higher education on the basis of their utility scores. For students in the possible STEM candidates group the difference in the utility scores was relatively small. Given their utility scores (Uc ≈ Us and/or Uc ≈ Ut), these students would fit a science or technical study almost equally well as they fitted their study chosen. Students in the no STEM candidates group clearly preferred their chosen study to a STEM study, because the differences in the utility scores (Uc versus Us and Ut) are much larger than in subgroup 2. Table 2 shows some descriptive results for the three subgroups. We included information regarding the students' chosen study profile (i.e. whether the students had taken the FSE in SCIENCE or in HEALTH) and their sex.

Table 2 *Descriptive results for the three subgroups*

	STEM candidates	Possible STEM candidates	No STEM candidates	Total
SCIENCE boys	8 (21%)	10 (26%)	20 (53%)	38
SCIENCE girls	5 (31%)	4 (25%)	7 (44%)	16
HEALTH boys	12 (13%)	17 (18%)	64 (69%)	93
HEALTH girls	27 (9%)	48 (15%)	242 (76%)	317
N	52	79	333	464

The results show that STEM candidates and possible STEM candidates are more often SCIENCE students (in particular SCIENCE girls) than HEALTH students. In absolute numbers, however, the HEALTH group is larger than the SCIENCE group. Students in the no STEM candidates group are more often HEALTH students than SCIENCE students.

The subjective norm component

The results for the three subgroups were compared to analyze whether the students' responses to the social influence items differed across the groups. Of the overall student group, 179 students (39%) indicated that they were influenced by significant others in choosing a study in higher education. This percentage was slightly lower in the STEM candidates group (31%) than in the other groups (possible STEM candidates 43%; no STEM candidates 39%), which tells us that in the STEM candidates group fewer students reported having been influenced than those in the other groups. The differences were, however, not significant, χ^2 (2) = 2.01. Among the 179 students, most students stated that their parents/guardians had influenced them (92%). Moreover, they indicated that they also had been influenced by friends and/or people from school (71% and 64% respectively) and to a lesser extent by their older brother or sister (40%). Few students reported that they were influenced by their partner (19%) or someone else (18%; these students usually mentioned other family members and study advisors)[8] . Table 3 shows per subgroup the responses of the students who reported that they were influenced by significant others (*N* = 179). The rows indicate the extent to which they were influenced (in their perception), by how many different people they were influenced, how large this influence was per significant other, and what their advice was.

On average, the students reported that they were influenced to a rather large extent by at least one of the six possible "sources" listed above (5.3 on a 7-point Likert-scale) and that they were influenced by 3 people on average. Both means are slightly higher among the STEM candidates, which indicates that more members of this group reported consequential social influence than the students in the other groups, and that they were influenced by more people (0.5 additional person) than the other students. Particularly the influence of parents/guardians was relatively large (4.5) for all students, followed by friends (3.0) and people from school (3.0). The influence of an older brother/sister, someone else, or a partner appeared much smaller. Students in the STEM candidates group reported more influence from their parents/guardians, friends, and people from school as compared with the students from the other subgroups. However, on a 7-point scale the differences among the subgroups were rather small.

The lower rows of Table 3 show the advice given by significant others (as perceived by the students). The students indicated that the people that had influenced them generally advised them to choose their current (non-STEM) study (5.1 on the influence-scale). At the second place we find medical studies (3.3); other studies were advised to a lesser extent (< 3).

[8] The percentages for the overall student group (*N* = 463) are 36% (parents/guardians), 27% (friends), 25% (people from school), 15% (older brother/sister), 7% (partner), and 7% (someone else).

Table 3 *Social influence (means and standard deviations), split by subgroup*

	STEM candidates	Possible STEM candidates	No STEM candidates	Total
Influenced to what extent?	5.5 (0.7)	5.1 (0.8)	5.3 (0.9)	5.3 (0.9)
Influenced by how many people?	3.5 (1.3)	3.0 (1.5)	3.0 (1.2)	3.0 (1.3)
Influenced by:				
parents/guardians	5.1 (1.1)	4.3 (1.6)	4.5 (1.5)	4.5 (1.5)
friends	3.4 (1.5)	2.8 (1.6)	3.0 (1.7)	3.0 (1.7)
partner	1.5 (1.1)	1.8 (1.6)	1.5 (1.1)	1.5 (1.2)
people from school	3.5 (2.0)	2.9 (1.9)	2.9 (1.8)	3.0 (1.8)
older brother/sister	2.4 (1.5)	1.8 (1.3)	2.0 (1.6)	2.0 (1.5)
someone else	1.7 (1.6)	1.8 (1.6)	1.7 (1.6)	1.7 (1.6)
Advice others:				
current study	4.7 (2.0)	5.2 (1.4)	5.1 (1.6)	5.1 (1.6)
science study	3.6 (1.9)	2.6 (1.5)	2.5 (1.7)	2.6 (1.7)
technical study	3.0 (2.0)	2.2 (1.5)	2.0 (1.3)	2.1 (1.5)
medical study	2.9 (1.7)	3.4 (2.0)	3.3 (2.1)	3.3 (2.0)
economical study	2.4 (1.4)	1.8 (1.4)	1.8 (1.2)	1.8 (1.3)
other study	3.0 (2.0)	1.8 (1.3)	1.8 (1.3)	1.9 (1.4)
N	16	34	129	179

When we consider the differences among the subgroups some important ones come up. The current study, medical studies, economical studies, and other studies seem to be advised to a lesser extent among STEM candidates than among possible STEM and no STEM candidates. However, science and technical studies are advised more often in the STEM candidates group than in the other subgroups. The advice reported by possible STEM and no STEM candidates are comparable. These results suggest that non-STEM students in the STEM candidates group who reported that they were influenced by significant others were more often advised to choose STEM than other non-STEM students who were influenced by significant others. Despite this extensive amount of advice, however, they had chosen a non-STEM study.

Test results Hypothesis 3

Table 4 shows the subjective norm components for all 6 advice-options (means and standard deviations). The results of the statistical tests are included in the rightmost column.

Table 4 *Subjective norm (means and standard deviations), split by subgroup*

	STEM candidates	Possible STEM candidates	No STEM candidates	Total	F (2, 179)
Current study [a]	25.9 (11.3)	26.9 (8.8)	27.3 (10.3)	27.1 (10.1)	0.13
Science study	19.9 (11.2)	13.3 (9.2)	13.0 (9.3)	13.7 (9.6)	3.77*
Technical study	16.8 (11.8)	11.4 (8.7)	10.4 (7.5)	11.2 (8.3)	4.24*
Medical study	16.2 (9.2)	17.9 (11.7)	17.5 (11.5)	17.4 (11.3)	0.13
Economical study	13.8 (8.6)	9.1 (6.8)	9.4 (7.1)	9.8 (7.3)	2.72
Other study	17.0 (12.2)	9.1 (7.1)	9.7 (7.4)	10.3 (8.1)	6.51**

Notes. * $p < .05$, ** $p < .01$; [a] One-tailed test.

The table shows no significant subgroup effect for the current study. This result signifies that students in all three subgroups were influenced to an equal extent to choose their current study, which was a non-STEM study. Based on this result we have to reject Hypothesis 3 that STEM candidates are more strongly influenced by significant others to choose a non-STEM study than possible STEM and no STEM candidates. Additionally, we found that STEM candidates were influenced to a larger extent than the possible STEM and no STEM candidates to choose science, technical, and also other studies. The effect sizes (partial eta-squared) are 0.04 (science studies), 0.05 (technical studies), and 0.07 (other studies). The fact that STEM candidates were more often advised to choose a science or a technical study than other students strengthens our argument for rejecting the third hypothesis, although for this group we had expected advice which was more directed at choosing the current, non-STEM study.

Additional analyses

We explored the underlying structure of the STEM candidates' utility scores to establish for which perceptions and stereotypes they deviated from those of the possible STEM and no STEM candidates. Because the students in the latter two subgroups appeared quite similar, as indicated in the previous sections, we combined them together in one group. We calculated the mean scores of the perception items (current study), the stereotype items (science and technical studies), and the assessment of importance items as we did in Table 1. Table 5 shows the differences in the mean item scores between the STEM candidates and the other non-STEM students. Test statistics (independent samples t-tests) are also included in the table (the *p*-values are shown between brackets). Table 6 indicates the corresponding effect sizes (Cohen's *d*) for the differences in the mean item scores.

Table 5 *Differences in mean item scores between STEM candidates and other non-STEM students (p-values between brackets)*

	Perceptions chosen study	Stereotypes science studies	Stereotypes technical studies	Assessment of importance
Difficulty level	0.23 (.300)	0.81 (.000)	0.41 (.013)	0.00 (.980)
Varied content	-0.80 (.000)	1.02 (.000)	1.00 (.000)	-0.11 (.401)
Interesting	-0.68 (.000)	1.21 (.000)	1.30 (.000)	-0.48 (.000)
Theoretical courses	-0.35 (.071)	0.04 (.812)	0.10 (.604)	0.10 (.581)
Specialization options	-1.19 (.000)	0.73 (.000)	0.60 (.000)	-0.46 (.013)
Options to choose	-1.20 (.000)	0.92 (.000)	0.58 (.001)	-0.26 (.152)
Achievement	-0.24 (.054)	1.35 (.000)	1.09 (.000)	0.05 (.732)
General development	-0.76 (.000)	0.83 (.000)	0.71 (.000)	-0.15 (.391)
Fits me	-0.86 (.000)	1.47 (.000)	1.24 (.000)	-0.16 (.172)
Job within half a year	-0.36 (.115)	0.44 (.022)	0.54 (.002)	0.02 (.910)
Job useful for society	-0.37 (.046)	0.67 (.000)	0.49 (.003)	-0.27 (.182)
Different job opportunities	-1.06 (.000)	0.95 (.000)	0.77 (.000)	-0.27 (.173)

Table 6 *Effect sizes (Cohen's d) for the differences in mean item scores between STEM candidates and other non-STEM students*

	Perceptions chosen study	Stereotypes science studies	Stereotypes technical studies	Assessment of importance
Difficulty level	-0.19	-0.71	-0.37	-0.01
Varied content	0.76	-0.77	-0.79	0.12
Interesting	0.78	-0.78	-0.84	0.62
Theoretical courses	0.26	-0.04	-0.07	-0.09
Specialization options	0.80	-0.49	-0.53	0.36
Options to choose	0.81	-0.81	-0.51	0.22
Achievement	0.28	-0.97	-0.78	-0.06
General development	0.74	-0.64	-0.60	0.12
Fits me	0.91	-1.00	-0.88	0.20
Job within half a year	0.27	-0.34	-0.46	-0.02
Job useful for society	0.35	-0.54	-0.44	0.20
Different job opportunities	0.70	-0.72	-0.68	0.20

The results show that as regards most items STEM candidates generally had less favourable perceptions of their current study and more favourable stereotypes of science and technical studies than other non-STEM students. This finding indicates that no particular item "is responsible for" the negative discrepancy scores (Us > Uc and/or Ut > Uc) of the STEM candidates. They were rather the result of an overall difference in perceptions and stereotypes. Nevertheless, three very large differences between STEM candidates and other non-STEM students can be observed in the tables. Table 6 shows that the effect sizes (Cohen's *d*) vary from -0.01 to -1.00. The first large difference concerns choice-options. Compared with the other non-STEM students, the STEM candidates felt that their current study offered only few *specialization options, options to choose,* and *different job opportunities.*

Apparently, only during their study did they realize that their options were limited. The second difference concerns the content of the STEM studies. Compared with those of the other non-STEM students, the STEM candidates' stereotypes of the items *varied content, interesting,* and *fits me* were more favourable. However, the mean scores (not presented here) indicate that their current study fitted them better than science and technical studies, while for this study they also scored higher on the item *interesting*. Thirdly, the STEM candidates had more favourable stereotypes of the item *achievement* than the other non-STEM students. Noteworthy is that, in the STEM candidates group, the average stereotype of the difficulty level of science and technical studies was more favourable than the average perception of the difficulty level of the students' current study.

For the *assessment of importance* items no large differences were found between the STEM candidates and the other non-STEM students (differences $\leq$ 0.5). All students had similar ideas about the importance of the items presented. The most notable differences were found for the items *interesting* and *specialization options*, on which STEM candidates had scored slightly lower than the other non-STEM students. It appeared that the STEM candidates found these items less important when choosing a study than the other non-STEM students.

Finally, we investigated the STEM candidates' actual study choices to understand which disciplines had generated their interest more than STEM studies. We found that they had mostly chosen studies in health care, which was the case for 19 students (37%). These were in general students who had taken their FSE in the HEALTH study profile at the end of secondary education. Other STEM candidates had chosen various options, among which social sciences, business administration, and education.

Conclusions and discussion

The present study has concentrated on the attitudes of students who were eligible for STEM studies but did not choose such a study in higher education. Our main interest was why these suitably qualified students did not continue their education in STEM (i.e. a science or technical study). To answer this question, we compared non-STEM students' attitudes towards STEM ("*stereotypes*") with their attitudes towards their study actually chosen ("*perceptions*"). In line with the basic principles of behavioural decision theory, we presumed that the students would choose a study that would best suit their subjective expectations in terms of utility (the best fitting option). Our results support Hypothesis 1 that, among non-STEM students, the utility scores on their chosen study were generally higher (more favourable) than those on science and technical studies. For the items *varied content* and *interesting*, but also for *general development* and *job useful for society* these students' perception scores as regards their chosen study were more favourable than their stereotypes of science-oriented studies. Moreover, our results confirm our expectation that non-STEM students' utility score on technical studies is, in general, higher than that on science studies (Hypothesis 2). Furthermore, the students' stereotypes of the future perspectives and choice-related perspectives of science studies were less favourable than their stereotypes of technical studies with respect to these items (and of their chosen study). This finding indicates that students' attitude towards technical studies was more favourable than their attitude towards science studies.

Based on the results presented, we can conclude that in general the students in our sample chose the option that best fitted their attitudes (e.g. Ajzen & Fishbein, 1980). For most students (72%; the no STEM candidates group), a STEM study was not an attractive alternative as compared to the study they had actually chosen. Nevertheless, we found that the stereotypes of science and/or technical studies of 11% of the students were more favourable than their perceptions of their chosen study (the STEM candidates group), and that there were only small differences in the utility scores of 17% of the students (the possible STEM candidates group). Exploratory analyses showed that STEM and possible STEM candidates were more often SCIENCE students (in particular SCIENCE girls) than HEALTH students. This result suggests that students who took the more advanced math/science courses in secondary education (the SCIENCE profile) but who did not continue in a science-oriented study, would have been more suitable for STEM studies than students who took the more basic math/science courses in secondary education (the HEALTH profile). As we expected, this holds particularly for SCIENCE girls. As regards their ability and attitudes, these students would definitely fit STEM studies in higher education.

Furthermore, we investigated whether the non-STEM students who would fit STEM studies (STEM candidates) were more strongly influenced by significant others to choose a non-STEM study than the other non-STEM students. Here the results were somewhat contradictory. STEM candidates experienced a stronger social influence from significant others (usually their parents, friends, and/or people from school) than other non-STEM students. However, all three subgroups (STEM candidates, possible STEM candidates, and no STEM candidates) were influenced to an equal extent to choose their current study (the non-STEM study). We therefore did not find support for Hypothesis 3. Although we expected a stronger influence with respect to the current non-STEM study among the STEM candidates, we found that they were more strongly influenced than other non-STEM students to choose science or technical studies. However, they had nevertheless chosen a non-STEM study despite the advice of significant others. This result conflicts with our finding that STEM candidates experienced the strongest social influence compared with other non-STEM students. We do not have a clear explanation for this difference. Nevertheless, most students were advised and supported to choose their current (non-STEM) study (compare e.g. Chhin et al., 2008; Leslie et al., 1998; Maple & Stage, 1991).

Finally, we investigated the non-STEM students who had chosen a less suitable option (STEM candidates) in more detail to establish what caused their high utility scores on science and/or technical studies compared with their low utility scores on their current study. The results showed that there was no particular item which caused this difference. It was more an overall difference in the degree of favourableness of the STEM candidates' perceptions of the current study and their stereotypes of science and technical studies compared with other non-STEM students' perceptions and stereotypes. The largest differences we observed concerned choice-options (STEM candidates had less favourable perceptions of their current study regarding this item than the other non-STEM students), the content of STEM studies (STEM candidates had more favourable stereotypes of science and technical studies regarding this item than the other non-STEM students), and the expected achievement in science and technical studies (STEM candidates' stereotypes were more favourable regarding this item). Furthermore, we found that many of the STEM candidates had actually chosen a study in health care instead of in STEM.

As our data suggest, for most students a STEM study was not an attractive alternative compared with the study of their choice. Consequently, we doubt whether active counselling would have increased these students' interest in STEM studies. However, one out of ten non-STEM students (who had taken the FSE in the SCIENCE or HEALTH profile) had a more favourable attitude towards STEM studies than towards their current study. Particularly SCIENCE girls belonged to this group and could have therefore taken advantage of adequate counselling. Unfortunately however, the influence of significant others on these students' study choices is still unclear. Although students who would fit a STEM study (STEM candidates) reported that they were influenced by their parents, their friends and/or people from school to choose their current non-STEM study, this social influence was practically the same for the other non-STEM students. More research is required into the actual impact of significant others on study choice to determine the differences in social influence among different student groups (e.g. SCIENCE girls, SCIENCE boys, HEALTH girls, and HEALTH boys).

Since the group with less favourable attitudes towards STEM is much larger than the number of students who would fit STEM in terms of their attitudes, we will reflect on some suggestions to change students' attitudes towards STEM. The research literature offers several ways to change people's attitudes. When we consider one's attitude to be a function of the strength and evaluation of one's salient beliefs about certain behaviour, attitude change will involve changing the supposed foundations of this state of mind (O'Keefe, 2002). For example, we could try to change one's beliefs and/or evaluations (in our case: *assessments of importance*). We could develop interventions to increase students' interest in science-oriented topics. Students can then experience that science is fun.

Nevertheless, Weisgram and Bigler (2007) report that girls' interest in science-oriented topics is actually unaffected by intervention programmes in which they learn about gender discrimination. These programmes do, however, influence their self-efficacy and belief in the value of science. Perhaps intervention programmes that provide students with adequate information about the numerous choice-options of STEM studies would be more successful. Another way of changing students' attitude towards STEM is to increase (or decrease) the strength of a belief and/or an evaluation. By conducting hands-on science experiments, students might experience that it is not as difficult as they expected. Consequently, the difficulty level of STEM studies may become less of a deal breaker when selecting a study. A third way of changing attitudes is to add new salient beliefs. Visiting an orientation day at the university can be very effective in bringing information to students' attention which was still unknown to them, such as opportunities to study abroad and the advantages of working together in research groups (Warps, 2001). Further, also schools could influence students' attitudes. Teachers could help students approach the subject choice process more rationally by re-questioning common beliefs about STEM. They could motivate students to reconsider the positive aspects of STEM, such as the assignments they liked during math and science classes, and make these beliefs more salient (and others less strong). However, in practice, persuasive efforts usually result in temporary rather than in long-term changes. Integrating several teacher and counsellor initiatives into the study profile or study choice process could partly resolve this problem. For instance, by talking about their experiences at a study orientation day students may develop new salient views and attitudes. Finally, if students are encouraged by their teachers to choose either a STEM or a non-STEM study, they are better capable of dealing with negative socialization pressures from other sources, such as the media or their peers.

Some final remarks need to be made about the data used in this study. Because the response group was not representative of the population, it has remained difficult to generalize our results. The student sample represented only 32% of all respondents approached. However, with respect to students' study profile choice our sample is representative for the Dutch student population. Furthermore, the sample size of students who would fit a STEM study (STEM candidates) was too small to draw far-reaching conclusions, while those about the importance of significant others are only tentative.

Despite these limitations, however, our study demonstrates that the constructs we derived from TRA can effectively be used to measure non-STEM students' attitudes towards STEM studies in higher education. Non-STEM students' stereotypes and perceptions are evidently related to their study choice. In conclusion, the results of our analyses indicate that there are specific student groups, such as SCIENCE girls, which would fit STEM studies in terms of their attitudes and abilities. This information could be used in offering these STEM candidates adequate counselling in the future.

Chapter 8

General Conclusions and Discussion

The studies presented in this dissertation were all conducted in the context of low participation rates of Dutch students in science-oriented courses in secondary education (i.e. advanced mathematics, chemistry, and physics) and in STEM courses in higher education (science, technology, engineering, and mathematics). In the Netherlands, few students choose to take their Final School Examinations (FSE) in the science & technology study profile (SCIENCE) at the end of secondary education. This profile includes advanced mathematics, chemistry, and physics courses and is mandatory for entering STEM studies in higher education. The objective of the dissertation lying before you has been twofold. The first objective was (1) to identify particular characteristics of students who enrolled in the SCIENCE profile and/or in a STEM study. More specifically, we were interested in the possible differences between SCIENCE/STEM and non-SCIENCE/non-STEM students with respect to characteristics such as ability, personality traits, study behaviour, and attitudes. The second objective was (2) to identify students within the non-SCIENCE/non-STEM group who would, on the basis of these characteristics, fit the SCIENCE profile and/or a STEM study. Also sex-differences concerning these issues were considered. These two objectives led us to conduct six empirical studies, which have all been described in this dissertation. In each of these studies we formulated a number of research questions and hypotheses largely based on theoretical insights and empirical evidence gathered by various researchers in the field. In each study, large quantitative datasets were used to answer the questions and test the hypotheses. The data used in this dissertation were collected as part of a large-scale longitudinal cohort study in the Netherlands, the "Cohort Studies in Secondary Education" (VOCL'99; in Dutch: "Voortgezet Onderwijs Cohort Leerlingen"). In this cohort study students are being followed in their educational career from the 7th grade onwards until they have completed their full-time education. The dataset provided us with a wealth of information regarding students' background and psychological characteristics. Moreover, the longitudinal character of the dataset offered us the opportunity to study the same students during several points in time throughout their educational career. Our research project focussed on the upper tracks of secondary education (senior general secondary education and pre-university education) and the first years of higher education. The studies presented in Chapters 2 up to and including 5 dealt with students in secondary education. In these chapters, we used data collected between 1999 and 2005. Chapters 6 and 7 described studies that included subsamples of the student population. These subsamples represented the students that had entered a study in higher education after succeeding their FSE.

Additional data concerning these students were collected by means of a follow-up questionnaire sent to the parental home addresses in 2008.

This final chapter begins with a summary of the main findings of this dissertation, containing a brief account of each study and the presentation of our general conclusions. After that, the subsequent discussion section first introduces the strengths and limitations of the overall research project. Next, we will briefly reflect on the overall results of this project and give some recommendations for future research. Finally, we will go into the practical implications of our research.

Summary of the main findings

Estimates of wasted science talent

At the end of the 9th grade, students choose one out of four possible combinations of school subjects, the so-called "study profiles", in which they take their FSE. The study profiles are: science & technology (SCIENCE), science & health (HEALTH), economics & society (ECONOMY), and culture & society (CULTURE). This mandatory study profile choice is the first opportunity for students to leave the STEM "pipeline". The first study (Chapter 2) addressed this topic, investigating how many students who chose a less science-oriented study profile (i.e. HEALTH, ECONOMY, or CULTURE) may have actually had a reasonable chance of success at the FSE in the SCIENCE study profile in secondary education. We used the average score of SCIENCE students on three math-related tests to establish how much math ability is required for taking the FSE in the SCIENCE profile. This average figure was used to identify the students among the other study profiles with sufficient math ability. This longitudinal study included 6,033 students in pre-university education (track A) and senior general secondary education (track B). It appeared that many students would have had a reasonable chance of success at the FSE if they had chosen the SCIENCE profile. In addition to those already engaged in SCIENCE, at least 20% of the track A students in the other profiles had sufficient math ability for SCIENCE. This was true for 23% of the track B students in the other profiles. Talented students were found across all study profiles and were both boys and girls. Approximately 1/4 of the non-SCIENCE boys and almost 1/5 of the non-SCIENCE girls in both tracks could have pursued SCIENCE but had chosen otherwise. So, we found minimum percentages of 20% (track A) and 23% (track B) of "wasted" science talent amongst the Dutch students in secondary education.

Are science students nerds?

Chapter 3 dealt with the stereotyped image of male science students as "nerds". We sought to discover whether science students in fact represent a certain type of the student population. Based on a literature review, we hypothesized that: (1) science students have lower scores on the personality factor Extraversion than other students, (2) science students have less social contacts than other students, (3) science students spend more time using a computer and other media than other students, and (4) science students spend less time on sports, relationships, and social contacts than other students. We used the questionnaire responses of 1,812 SCIENCE boys in secondary education. In line with the hypotheses, the results showed that these boys had lower scores on the personality factor Extraversion than boys in other study profiles, and that they had less female friends than other boys. The latter result, however, only applied to track A students. Moreover, it did not hold true for the number of male friends. Furthermore, we did not find support for the third hypothesis. With respect to the fourth hypothesis, it appeared that SCIENCE boys indeed spent less time on sports, relationships, and social contacts than other boys, although the differences between the two groups were (very) small. Both the scores on the personality factor Extraversion and on the number of female friends (in track A) to some extent predicted whether students were engaged in SCIENCE or in other profiles. All in all however, the results suggested that stereotyping male science students as nerds is largely unfounded.

The personality – study profile match

The third study (Chapter 4) explored the relationship between personality characteristics and students' study profile choice in secondary education. The main research question here was: "Are there differences in personality characteristics among students choosing different study profiles?" Both boys and girls were included in this study. Using the Five-Factor Personality Inventory (FFPI) of Hendriks, Hofstee, and De Raad (1999a) to measure 3,992 9^{th} grade students' personality characteristics, we found significant differences among the student groups (SCIENCE, HEALTH, ECONOMY, and CULTURE) with respect to all five personality factors (Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Autonomy). In general, the SCIENCE and HEALTH profiles seemed to attract more introverted students, whereas the ECONOMY and CULTURE profiles drew more extraverted people. As expected, the negative association between Extraversion and the choice of SCIENCE remained significant when students' math ability was taken into account. Moreover, we found that the more science-oriented the profile, the higher the scores on the factors Conscientiousness and Emotional Stability. Additionally, CULTURE students scores' on Agreeableness appeared to be higher than those of ECONOMY students on this item. Finally, boys in SCIENCE and ECONOMY had lower scores on Autonomy than girls in these profiles, whereas the scores of CULTURE girls on this item were lower than those of CULTURE boys. All things considered, we found support for Holland's theory (1997) that students' interests and, consequently, their subject choices are related to their personality.

Requirements for success in the SCIENCE profile

In Chapter 5, we examined what students require to be successful in advanced mathematics, chemistry, and physics at the FSE. In the first part of this study, we explored (sex-)differences in math ability among students in different study profiles, as was done in Chapter 2. This part of the study included 6,033 students. The results showed that SCIENCE students had higher scores on math ability than other students and that boys had, in general, higher scores than girls. In addition, the data supported our hypothesis that SCIENCE girls score higher on math ability than SCIENCE boys, whereas girls in other study profiles score lower on this variable than boys in other study profiles. Only the most capable girls had chosen SCIENCE. The second part of the study included 720 students who had taken their FSE in the SCIENCE study profile. As predictors of student achievement (i.e. students' GPA) the research literature has, among other things, identified *cognitive ability*, *achievement motivation*, and *homework time*. In view of our aim of extending the current knowledge about this issue we replicated the previous findings in the SCIENCE students group and clarified the relations among math ability, academic achievement motivation (AAM), and homework time (HWT) by predicting their examination grades in advanced math, chemistry, and physics. For measuring AAM and HWT we used a questionnaire. Regression analyses demonstrated that math ability and AAM contributed additively to the prediction of the students' attainment in these three science subjects. In line with the hypotheses, we found significant positive effects of math ability and AAM on the SCIENCE students' examination grades for these subjects. However, the expected positive effect of average time spent on homework on SCIENCE students' examination grades was not found. This was also the case for the possible mediating and moderating effects of math ability, AAM, and HWT on SCIENCE students' examination grades. Unexpectedly, we did find a *suppression effect*; the relation between AAM and SCIENCE students' examination grades was stronger for students who spent little time on their homework than for those who spent a lot of time on their homework. Most importantly, the results suggested that AAM is just as important as math ability in predicting the achievements of SCIENCE students.

Stereotypes and perceptions of STEM studies

As became apparent in Chapter 6, many students who had taken the FSE in the SCIENCE study profile did not continue their educational career by opting for a STEM study. Instead they chose a non-STEM study in higher education and, therefore, wasted their science talent. In the fifth study, we tried to find out why these sufficiently capable students did not choose a STEM study. For this purpose, we investigated the attitudes towards science and technical studies of those who had and those who had not chosen a STEM study (and thereby had or had no experience, respectively, with STEM in higher education). The STEM students' attitudes towards the chosen study (based on experience) were referred to as *"perceptions"*, while the non-STEM students' attitudes towards STEM studies (not based on experience) were labelled *"stereotypes"*. The comparison between the stereotypes and perceptions revealed whether the former were in any way a reflection of reality (as perceived by the STEM students). For example, we compared the non-STEM students' stereotypes of the job perspectives of technical studies with the job perspective perceptions of the students who had actually chosen a technical study. In our research, which included 1,935 students in higher education (mostly 2nd and 3rd year students), six hypotheses were tested. We first analyzed the non-STEM students' stereotypes of science and technical studies. The analysis supported our expectation that among these students the stereotypes of technical studies were more favourable than those of science studies (e.g. regarding the career perspectives and the expected narrow focus of science studies). Moreover, the SCIENCE students' stereotypes of STEM studies were generally more favourable than those of non-SCIENCE students. As expected, some interaction-effects between study profile (SCIENCE vs. non-SCIENCE) and sex on non-STEM students' stereotypes of science and technical studies were found. SCIENCE-girls had, in general, more favourable stereotypes than SCIENCE boys and non-SCIENCE boys and girls. Nevertheless, they had not chosen a STEM study in higher education. Secondly, we investigated the students' perceptions of their study actually chosen (i.e. non-STEM study, science study, or technical study). The results indicated that the STEM students' perceptions of their current study generally did not deviate from the other students' perceptions of their current study, with a few minor exceptions. Thirdly, we compared the non-STEM students' stereotypes of STEM studies with the STEM students' perceptions of their STEM studies. An important finding was that non-STEM students expected science studies to be less varied in terms of content than STEM students actually perceived their study. Moreover, many non-STEM students felt that a science or technical study would not fit them (e.g. general fit, expected achievement), whereas STEM students did perceive an adequate fit. The content of technical studies was stereotyped and perceived alike. Finally, a number of complex interaction-effects were tested. Our results partly confirmed our expectation that among the STEM students the non-SCIENCE students' perceptions of their current science or technical study were more favourable than those of the SCIENCE students with respect to their current study, whereas among non-STEM students the non-SCIENCE students' stereotypes of science or technical studies were less favourable than the SCIENCE students' stereotypes of these studies. However, we did not find support for our hypothesis that the differences between the stereotypes and perceptions of STEM studies differ between the sexes.

Why some suitably qualified students did not choose STEM

The main aim of the last study (Chapter 7) was to understand why some suitably qualified students did not continue their education by choosing a STEM study in higher education, despite their previous interest in science-related topics in secondary education. We based this study on the multi-attribute utility theory, using an approach related to the theory of reasoned action (Fishbein & Ajzen, 2010). This research included 477 students who had taken their FSE in the SCIENCE or HEALTH study profile in secondary education but who had not opted for a science or technical study in higher education. The attitudes of these students towards STEM studies were compared with their attitudes toward their current (non-STEM) study. As expected, most non-STEM students had chosen the best "fitting" option as regards their attitudes. However, one out of ten non-STEM students, particularly SCIENCE-girls, had a more favourable attitude towards STEM studies than toward their current study (mainly with regard to choice-options, content, and achievement). In addition, the non-STEM students' attitude towards technical studies was more favourable than their attitude towards science studies. The hypothesis that significant others (e.g. parents, peers, people from school) had advised these students to leave the STEM pipeline was, however, not supported by our data.

Conclusions

Summarizing, given our primary research objectives, the studies conducted have yielded useful findings. Among the students who enrolled in the SCIENCE profile and/or in a STEM study we identified various characteristics with respect to ability, personality, study behaviour, and attitudes (our first objective). In addition, we identified many students within the non-SCIENCE/non-STEM group who would, on the basis of these characteristics, fit the SCIENCE profile and/or a STEM study (the second objective). With respect to ability we found that, on average, SCIENCE students scored higher on math ability than other students. The students' average math ability scores decreased gradually as the study profile chosen was less science-oriented. We nevertheless found that in addition to those already in the SCIENCE study profile, approximately 1/4 of the non-SCIENCE boys and almost 1/5 of the non-SCIENCE girls possessed sufficient math ability for SCIENCE in secondary education. At least 20% of the track A non-SCIENCE students and 23% of the track B non-SCIENCE students had a math ability score equal to or higher than the SCIENCE students' average math ability, and had thus wasted their science talent. Notwithstanding the importance of math ability, however, the analyses of Chapter 5 also indicated that students' academic achievement motivation was equally important for being successful in advanced mathematics, chemistry, and physics courses at the FSE.

With respect to personality characteristics, we found that, on the whole, SCIENCE students did not differ much from the other students. Few specific characteristics resulted from our analyses. In general, the SCIENCE students were indeed less extraverted than the other students, but other less favourable characteristics (e.g. those associated with the nerd stereotype) were hardly confirmed in our studies. Moreover, we also found introverted students among the other study profiles. Although the results of Chapter 4 supported our expectation that study profile choices are related to students' personality characteristics, we argue on the basis of our findings that a fixed typology of distinctive science student characteristics is largely unfounded. In terms of these characteristics also many other students (both boys and girls) would fit the SCIENCE study profile apart from those who took their FSE in SCIENCE.

In our studies conducted in higher education, we observed several differences in attitudes towards the STEM studies. We found, for instance, that many non-STEM students had unfavourable stereotypes of science studies and that some non-STEM girls who had taken their FSE in the SCIENCE profile had favourable stereotypes of technical studies. The non-STEM students' unfavourable stereotypes were not always a reflection of "reality", as was perceived by the students who actually participated in a science or technical study. Moreover, given their attitudes, one out of ten non-STEM students, in particular SCIENCE-girls, would most probably have better fitted a STEM study than their current non-STEM study. We consider this also as an example of wasted science talent.

Discussion

Strengths and limitations of the research project

Given that each chapter in this dissertation includes a separate discussion section which briefly indicates the strengths and limitations of the study in question, the issues presented here generally deal with the overall research project.

In our view the most important strength of the studies in this dissertation has been formed by the data used for the analyses. The large-scale VOCL'99 dataset provided valuable information to conduct studies in both secondary education and in the first years of higher education. As we were able to follow the same student populations for many years, we could study the several points in time during which students with science talent can leave the STEM pipeline. Unfortunately however, the dataset we used was in many cases incomplete. The more our data collection progressed, the more the amount of missing data increased, which was mainly due to the growing non-response to the questionnaires used from the VOCL'99 study. Particularly the higher education students' response to our follow-up questionnaire was disappointing. Efforts to increase the response rate failed (Rekers-Mombarg, Korpershoek, Kuyper, & Van der Werf, 2010). Although we do believe that model-based imputation can be a useful tool to increase the number of cases that can be used in the analyses, we did not use this approach in this research project. Particularly the non-response group in our higher education sample was large. Of most of these non-respondents it is unknown why they did not respond to our follow-up questionnaire. To begin with, a considerable group did not receive the questionnaire, and others may just have decided not to respond. The questionnaires were sent to the parental home addresses, as the students might frequently change address and/or not always read their incoming post. As a result, we were unable to establish whether the data were missing *completely at random*, *at random*, or *not at random*. For this reason, we decided to perform a non-response analysis by making an inventory of the missing items throughout the studies. In general our analysis did not show many differences between the response and the non-response groups with respect to their background characteristics. Moreover, the remaining dataset was still reasonably large. As far as we were concerned, therefore, our database was still sufficiently suitable for generalizing our results with respect to the overall track A and B student samples of the Dutch secondary education. To confirm our findings, however, we nonetheless suggest repeating the studies, particularly those concerning higher education.

The second strength of the studies presented in this dissertation is that they yielded important insights into the often complicated relationships between the determinants of students' choice behaviour. We found empirical evidence for the proposition that a large amount of science talent is currently wasted in the Dutch secondary and higher education segments. Moreover, we adopted an innovative approach to identify the students who would have been fit to take up the SCIENCE study profile in secondary education and/or STEM studies in higher education. In Chapters 2 - 5 we used characteristics of SCIENCE students as the indicators of the characteristics required for choosing SCIENCE in secondary education. In these studies, we compared these particular characteristics of SCIENCE students (e.g. their math ability) with the characteristics of students who had chosen HEALTH, ECONOMY, or CULTURE. Similarly, in the studies presented in Chapters 6 and 7 STEM students' attitudes and perceptions as regards STEM studies in higher education were used to identify the non-STEM students who would fit a science-oriented educational career. Making these comparisons proved to be a useful approach to the identification of wasted science talent in Dutch secondary and higher education.

The third strength we would like to present here concerns the approach we used in Chapter 7. Here, the basic principles of behavioural decision theory were used as a theoretical framework to better understand students' educational choices. The study presented in this chapter was built on the multi-attribute utility theory (MAUT) on the basis of an approach related to the theory of reasoned action (TRA; Fishbein & Ajzen, 2010). We used some constructs from TRA to measure the non-STEM students' attitudes towards STEM studies in higher education. Following MAUT, we evaluated three alternatives (i.e. three disciplines students could choose in higher education) for each individual. We searched for the students' "optimal" choices as regards their attitudes towards the three alternatives. This procedure, a combination of MAUT and TRA, is new in the research field. It has proven to be a valuable and useful approach to enhancing our general understanding of why some suitably qualified students do not continue their educational career by choosing a STEM study.

A possible limitation we would like to point out is associated with the construct *math ability* we used throughout the thesis. In the empirical studies presented in Chapters 2 - 5, we used students' math ability as an indicator of students' science talent. The math ability construct was based on three math-related tests, regarding which we stated that they "in essence represent a combination of nature (ability) and nurture (achievement)". Although cognitive ability is, by far, proven to be the best predictor of school achievement (Gagné & St Père, 2001), separating the constructs ability and achievement is difficult in a domain where people are educated (Carroll & Horn, 1981). Hence, we believe that our combined scores based on ability as well as on achievement increased the reliability and validity of our math ability measure as opposed to using a single achievement test. A discussion covering all aspects connected with the question which construct should be used is, however, beyond the scope of this dissertation. In our view, our clear definition of the measures that we used in our study is sufficient to provide the necessary information regarding such an ambiguous construct. Nevertheless, we acknowledge that math ability is only a limited indicator of the broader construct of science talent. The predictive value of math ability on students' GPA in advanced math, chemistry, and physics was modest. We will return to this point in the following section.

Suggestions for future research

In this section we will reflect on some of the main conclusions of our studies. Following from our results, we have some suggestions regarding the issues to be addressed by educational researchers in future studies.

In Chapter 2, we investigated how many students who did not take their FSE in the SCIENCE study profile in secondary education, would have had a reasonable chance of success at the FSE in this profile if they had opted for it on the basis of their math ability. We based our measure of math ability on the students' achievement in three math-related tests. As we pointed out in Chapter 2, we did not have independent tests for chemistry and physics at our disposal, whereas it would be reasonable to assume that science talent entails more than math ability. We therefore suggest that in future studies addressing this issue also students' achievement in chemistry and physics should be taken into consideration. However, we would like to stress that we first need full knowledge of the exact requirements for a successful STEM career. These requirements are to large extent still unknown, which is why this topic needs further attention in future educational research. It is as yet unclear which variables sufficiently predict success in STEM studies and careers. Usually, meeting the formal entry requirements of STEM studies in higher education is sufficient for a successful STEM career, because prior success generally has a positive effect on the future success in a similar domain. But how important are students' examination grades as compared to their interest in science-related topics and their motivation to put effort into complicated assignments (see Chapter 5)? In addition, we suggest paying special attention to sex-differences in these matters. In secondary education, SCIENCE girls have, on average, higher scores on math ability than SCIENCE boys. We expect this imbalance to remain an issue in STEM studies in higher education. Insight into this issue would contribute to the general understanding of which students would fit a STEM career. This knowledge is certainly required for continuing the present research.

Additionally, we suggest following the students throughout higher education until their entrance into the job market. Such an analysis would provide information regarding the *definitive* utilization of science talent. Students who completed a science-oriented study might still have left the STEM pipeline upon entering the job market after graduation. In addition, students who left the pipeline in earlier stages of their educational career might have re-entered the STEM pipeline by starting a science-related career with the aid of additional courses outside their full-time education. Insight into these participation rates may provide more precise long-term estimates regarding the exact percentage of students who do not choose to utilize their science talent.

In Chapters 3 and 4, we found several connections between students' personality characteristics and their study profile choices in secondary education. Based on our studies, introverted students would probably better fit a science-oriented field of study (e.g. the SCIENCE study profile) than extraverted students. Consequently, stimulating introverted students to choose the SCIENCE profile in secondary education might be more effective than trying to convince extraverted students to pursue a math/science career. However, in the present study the actual influence of personality characteristics on students' study profile choice was not investigated. Hence, in addition to common explanatory factors, such as ability, background characteristics, and attitudes, we suggest including personality as possible explanatory factor in the educational choice models (e.g. Van Langen, 2005) in future studies. Based on our results, we argue that personality characteristics form an important additional item to be considered when trying to explain students' choice behaviour in education. Additionally, although we found support for Holland's theory (1997) that students' subject choices (which to some extent refer to their interests) are related to their personality, still more research is required to investigate whether the personality differences we found are also relevant in higher education. For example, are STEM students on average less extraverted than non-STEM students?

The findings of Chapter 6 have enhanced our understanding of the attitudes of science-talented students towards STEM studies in higher education. Of the non-STEM students, the SCIENCE students had, in general, more favourable stereotypes of STEM studies than the non-SCIENCE students. Given these insights, it could be argued that *more experience* with math- and science-related topics could result in more favourable attitudes towards STEM studies and, consequently, in an increased STEM entry. More experience could be gained by following one extra year of advanced mathematics, chemistry, and physics courses. When viewing science talent in terms of developing expertise (Sternberg, 1999), the option to drop advanced mathematics and science courses at the end of the 9th grade in the Dutch educational system is questionable. More experience with math/science topics could be beneficial for students' educational career. It would be worthwhile to know the benefits of one extra year of math education for students' self-confidence in math and, consequently, for increasing students' choice of SCIENCE in secondary education. Evidently, large-scale longitudinal studies in an experimental setting are required to resolve this issue.

Additionally, we suggest examining the impact of science talent as compared with, for example, other talents (e.g. linguistic talent), with respect to several educational outcomes. For instance, what is the impact of these talents on students' study profile choices in secondary education (e.g. Uerz, Dekkers, & Beguin, 2004), their achievement at the FSE at the end of secondary education, their study choices in higher education and, finally, their progress in their higher educational study? In this way, one could assess the benefits of having particular talents (e.g. science talent or linguistic talent) in choosing a particular educational career. For instance, Uerz et al. (2004) studied the effect of the comparative advantage of mathematics (the gap between the mathematics and language scores on achievement tests) on the number of science subjects chosen for the FSE. They concluded that the gap between mathematics and language skills contributed considerably to the choice of science subjects. Students with a comparative advantage in mathematics choose more science subjects for their FSE than those where the gap between maths and language is less marked (Uerz et al., 2004, p. 180). We suggest repeating this analysis in the current situation in which students have to choose one out of the four possible study profiles.

Another matter we would like to point out here concerns the investigation of the effect of significant others (e.g. parents) on students' educational choices. In Chapter 7, we used retrospective questions to measure this effect. In our follow-up questionnaire we asked the students to indicate whether they were influenced by significant others in their study choice. As the students had made their study choice at least two years before the data collection, they may have underestimated the actual impact of others at the time, for example, they might have forgotten that they were influenced by others. It is also plausible that the students (unconsciously) enhanced their motivation for their study choice in hindsight. Based on the theory of cognitive dissonance (Festinger, 1957), people tend to reduce the inconsistency between the negative characteristics of the chosen alternative and the positive characteristics of the not chosen alternative in order to enhance their motivation for their decision. There is a tendency to justify decisions in retrospection, that is, to reduce the resulting dissonance. Because our questions concerned study choices made in the past, it is likely that the students believed in hindsight that their choice was made more or less independently of their social environment. In contrast, the impact of significant others on study choice could also be overestimated; for example, students who regret their study choice preferably blame others for their wrong decision. That is, people usually try to avoid post-decisional regret (e.g. Bell, 1982), which means that in this case the students would have been inclined to overestimate the effect of significant others on their decision. So they avoided the post-decision dissonance by blaming others, whereby the dissonance became salient. We put forward the idea to apply the model proposed by Fishbein and Ajzen (2010) to illustrate the effect of the subjective norm on students' study choice in higher education. In their integrative model, both descriptive and injunctive normative beliefs are linked to the subjective norm, which in turn is linked to people's intention to exhibit certain behaviour. This means that the explanatory model of choice behaviour should not only include the impact of what other people think a person should do (in their perception), but also the impact of what other people actually do. As one third of the students in higher education stated that they were influenced by their parents, people from school, and/or their peers in their study choice (see Chapter 7), social influence can be a relevant factor in students' choice behaviour. In studying the effect of social influence on students' study choice in higher education the revised Fishbein and Ajzen (2010) model would be a suitable tool, since it conveniently has less difficulty with retrospective measurement issues and, more importantly, enables one to grasp the influence of significant others on students' study choices more accurately.

Related to the previous suggestions, we suggest an elaboration of the approach adopted in Chapter 7. For example, one could use a similar procedure in analyzing students' study profile choices in secondary education. The attitude constructs of TRA can then be applied to measure the students' attitudes towards the four alternatives (SCIENCE, HEALTH, ECONOMY, and CULTURE). As we did in our study, students' optimal choice as regards their attitudes can be examined and compared with their actual study profile choice by means of their utility scores for each alternative. Such a study could support our conclusion that combining general MAUT and the specific TRA models provides valuable insights into students' choice behaviour.

Practical implications

The major implication of this study for the educational practitioner is that apart from the more subjective ideas about the suitability of specific school subjects or higher education studies, he/she should also recognize the importance of using objective achievement measures when advising students. Given the results of our studies, we believe that curriculum-independent assessments of student achievement in (in any case) mathematics, chemistry, and physics at the end of the 9th grade could increase the participation rates in the SCIENCE study profile and, subsequently, increase students' entry in STEM studies in higher education. Particularly girls would benefit from these assessments. Few girls choose to take their FSE in the SCIENCE profile, even if they have the ability to do so, partly because of their generally lower self-concept with respect to math achievement (e.g. Crombie et al., 2005; Van Langen, 2005). As course marks can measure performance as well as effort, objective assessments are, in our view, certainly appropriate for such an important decision in students' educational career. However, these test results should be part of a standard package of career counselling advice offered to students by their teachers and mentors at school.

Given the objective to increase students' participation in science-oriented careers, we suggest the introduction of two broad tracks rather than four separate study profiles in secondary education. That is, we propose a science-oriented track that combines the SCIENCE and HEALTH profile and a society-oriented track that combines the ECONOMY and CULTURE profile (see also Korpershoek, Kuyper, & Van der Werf, 2007). In this way, students will be offered a broad set of school subjects, which prepares them for a variety of courses in higher education. Although the study profiles were initially introduced to offer students a more focussed preparatory trajectory by means of recognizable and more coherent study programmes preparing for specific courses in higher education, the early subdivision into four study profiles has not been in line with the stated objective (e.g. Van Langen, Rekers-Mombarg, & Dekkers, 2008). It was expected that introducing four study profiles would decrease the sex-specific subject choice, but the opposite occurred. Although the number has increased in the recent years (Van Langen & Vierke, 2009), only few students (girls in particular) yet meet the criteria to enter STEM studies in the Netherlands. A broad science-oriented track would give students the opportunity to develop their expertise (see also Sternberg, 1999) in science-oriented topics. We believe that such a system would increase students' interest in science-oriented studies in higher education. As suggested by our results, many HEALTH students have sufficient math ability to take the FSE in the SCIENCE study profile instead of in HEALTH. We argue that in the system suggested more HEALTH students would take a STEM study into serious consideration. In this system students would be offered a solid basis in a broad variety of science-topics, which would simply make them "feel" better prepared for STEM and SCIENCE. Currently, only one fifth of the HEALTH students continue their education in a STEM study (Statistics Netherlands, 2010). Besides, it is not only girls who make sex-specific occupational choices, although they are usually the main focus of attention (Lightbody & Siann, 1997). The distribution of students across the four study profiles in the Netherlands (see Table 1 in Appendix A) clearly shows that boys generally choose "traditional" economical and science-oriented fields of study. We expect that a system with two broad tracks could result in less sex-specific subject choices by both girls and boys. Since the introduction of the study profiles in 1998, several schools have introduced the broad tracks suggested, although not all schools offer this opportunity to their students. Despite the advice of the so-called "Profielcommissie" (Bruning & De Rooy, 2006) and positive reactions from universities, these structural adjustments did not form part of the mandatory changes applied to the structure of the study profiles in 2007. Until today, it is still unclear which system is more effective as regards the utilization of science talent, the early selection system with four study profiles or the system with two broad tracks. Regrettably, a longitudinal study that compares the effect of these two systems on students' study profile choice in secondary education and students' study choice in higher education has not been conducted yet. Although in our view the introduction of two broad-oriented tracks will increase STEM participation, extensive scientific research is still required to evaluate the definitive impact of the suggested system on study choice.

From the students' point of view, however, an early selection of school subjects is not that problematic. Research has shown that students are generally not inclined to change their initial study profile (Second Phase Advisory Point, 2005) and that they usually remain satisfied with their earlier study profile choice (De Vries & Van der Velden, 2005; Korpershoek, Kuyper, & Van der Werf, 2006). In hindsight, less than 10 percent of the students in the 11^{th} grade would have chosen another study profile (Korpershoek et al., 2006). Moreover, more than 85 percent of the students in higher education have indicated that in hindsight they would have chosen the same preparatory study profile again (De Vries & Van der Velden, 2005). As we found in Chapter 7, most students have chosen the best suitable option (i.e. a science study, a technical study, or another study) in higher education as regards their attitudes toward these three choice options. Likewise, the Dutch Education Inspectorate (in Dutch: "Inspectie van het Onderwijs"; 2003) reports that nowadays students make their educational choices more consciously than before the introduction of the study profiles in 1998.

To conclude, all in all the research project presented in this dissertation has contributed to the current body of knowledge about wasted science talent in education. It has yielded valuable findings and offered several suggestions for educational practice to increase the participation rates in science-oriented studies. Evidently, the effects of the practical implications suggested in this thesis should be further investigated in future studies.

Appendix A

The Dutch Educational System

In the Netherlands, students enter secondary education (7th grade) at age 12 or 13. Based on their previous achievement and the primary school teacher's advice students enter one of the three basic tracks in secondary education: preparatory secondary vocational education (track C), senior general secondary education (track B), or pre-university education (track A). The first track (the lowest track, duration four years) prepares students for senior secondary vocational education, which at most belongs to level 4 (post-secondary non-tertiary education) of the 1997 International Standard Classification of Education (ISCED97). The two latter tracks prepare students for tertiary education; senior general secondary education (the middle track, duration five years) prepares students for higher professional education (in Dutch "HBO") and pre-university education (the highest track, duration six years) prepares students for university (in Dutch "WO"). Both forms of higher education belong to level 5a of ISCED97. Higher professional education is also accessible for pre-university students. Moreover, students in higher professional education who completed the foundation year (in Dutch: "propedeuse") at the end of their first year can usually switch to a university study within a similar discipline. For both forms of higher education passing the Final School Examinations (FSE) at the end of secondary education is, in principle, sufficient for admission. However, for many disciplines additional requirements are formulated, for example the choice of examination subjects.

The remaining description of the educational system is limited to the upper years of the highest two tracks in secondary education (tracks A and B) for two reasons. First of all, the upper years are the first opportunity for students to choose between different school subjects. Secondly, track C does not prepare students (directly) for higher education, whereas the research project presented in this dissertation focusses on students' participation in STEM studies in higher education only.

The Dutch secondary educational system was extensively changed in 1998. A new educational concept was introduced in the upper years of tracks A and B, called "the second stage of secondary education" (in Dutch: "de tweede fase"). All schools for senior general secondary education and pre-university education implemented this new educational concept. The objective was threefold: (1) to improve the link between secondary education and higher education, (2) to modernize the study programs in upper secondary education and to give students a more focused preparation in recognizable and more coherent study programs for specific courses in higher education, and (3) to give schools more freedom in method choice in the study program for upper secondary education. One of the mandatory changes was the introduction of four study profiles;

science & technology (SCIENCE), science & health (HEALTH), economics & society (ECONOMY), and culture & society (CULTURE). In addition to the specific profile subjects, all students must take a number of mandatory subjects such as Dutch and English language, and a number of elective subjects. The study profiles were developed to give students a better preparation for the sectors in which our society is divided. Meanwhile, the distribution of students across the study profiles is rather unequal and the choices are highly sex-specific. Table 1 gives an overview of the distribution of all track A and B students across the study profiles in 2008 (Statistics Netherlands, 2010), split by sex.

Table 1 *Study profile choices of students taking their examinations in 2008 (split by track and sex)*

	Track A			Track B		
	% total	% boys	% girls	% total	% boys	% girls
SCIENCE	11.3	21.1	2.9	8.4	16.2	1.3
HEALTH	32.0	27.3	36.1	18.8	17.8	19.7
ECONOMY	30.7	35.6	26.5	36.6	47.8	26.6
CULTURE	19.5	6.5	30.8	33.0	13.3	50.6
SCIENCE + HEALTH	5.7	9.0	2.9	2.3	3.9	0.8
ECONOMY + CULTURE	0.7	0.6	0.8	1.0	0.9	1.0
Other combinations	0.1	<0.1	0.1	0.0	0.0	0.0

An optional change in the educational innovation was the introduction of a new teaching concept, the so-called "studiehuis". Within this educational concept students learned to actively and independently adopt knowledge and skills. The suggested improvements were expected to lead to better utilization of talents, in other words, an increasing learning output (Second Phase Advisory Point, 2005). Due to disappointing results, a number of changes were introduced in the structure of the study profiles in 2007. However, these changes did not apply to the students included in the VOCL'99 study, which is why we chose not to elaborate on these changes here.

Appendix B

Additional Analyses Chapter 4

In Chapter 4, we explored the relationship between personality characteristics and students' study profile choice in secondary education. To explore this relationship among students with science talent, we repeated the analyses in the subsample of students with "high math ability" (see Chapter 2). The results of these analyses are presented in this Appendix. Personality characteristics of students in the "high math ability" group were available for 1,099 students, which were 627 boys (57%) and 472 girls (43%). Table 4 presents the personality scores of these students.

Table 4 *Descriptive results of the students' personality scores (overall and per study profile) for the "high math ability" group*

	SCIENCE	HEALTH	ECONOMY	CULTURE	Total
Means and standard deviations:					
Extraversion	0.66 (0.94)	1.12 (0.93)	1.22 (0.94)	1.29 (0.98)	1.06 (0.97)
Agreeableness	1.66 (0.89)	2.05 (1.02)	1.63 (1.09)	2.22 (1.05)	1.85 (1.04)
Conscientiousness	0.25 (1.11)	0.00 (1.19)	-0.05 (1.09)	-0.17 (1.08)	0.02 (1.13)
Emotional Stability	1.53 (0.82)	1.20 (0.95)	1.22 (0.88)	0.82 (1.16)	1.23 (0.95)
Autonomy	0.66 (0.82)	0.81 (0.91)	0.75 (0.91)	0.90 (1.07)	0.77 (0.92)
Average sex-difference (boys minus girls):					
Extraversion	-0.52	-0.17	-0.41	-0.26	-0.43
Agreeableness	-0.66	-0.65	-0.87	-0.59	-0.76
Conscientiousness	0.24	-0.02	0.09	0.04	0.16
Emotional Stability	0.68	0.43	0.54	1.13	0.64
Autonomy	-0.60	0.28	-0.11	0.07	-0.08

In general, the patterns in personality differences that evolved in the overall student sample were also found in the subsample. Among high math ability students, the scores on Extraversion increased monotonically from SCIENCE to CULTURE students and the scores on Conscientiousness decreased monotonically from SCIENCE to CULTURE students. Again, SCIENCE students had lower scores on Extraversion and Agreeableness (in the subsample except for ECONOMY students) and higher scores on Emotional Stability than the other students. As in the overall student sample, the sex-differences we found were in accordance with the literature.

Analyses of variance were performed on the five personality characteristics. Profile, sex, and the interaction between these two variables were included in the analyses. Again, students' math ability was taken into account in the analysis as a covariate. Table 5 shows the results.

Table 5 *Covariance analyses of the five personality factors for the "high math ability" group*

	F^a	p-value	η^2
Extraversion (R^2 = .09)			
Mathematical ability	10.82	.00*	.01
Profile	3.16	.02*	.01
Sex	20.15	.00**	.02
Profile x Sex	1.49	.22	.00
Agreeableness (R^2 = .15)			
Mathematical ability	1.94	.16	.00
Profile	3.48	.02*	.01
Sex	72.47	.00**	.06
Profile x Sex	1.06	.36	.00
Conscientiousness (R^2 = .02)			
Mathematical ability	4.08	.04*	.00
Profile	0.83	.48	.00
Sex	0.94	.33	.00
Profile x Sex	0.45	.72	.00
Emotional Stability (R^2 = .13)			
Mathematical ability	0.37	.54	.00
Profile	0.51	.67	.00
Sex	85.35	.00**	.07
Profile x Sex	3.66	.01*	.01
Autonomy (R^2 = .02)			
Mathematical ability	0.06	.81	.00
Profile	1.11	.35	.00
Sex	1.46	.23	.00
Profile x Sex	6.25	.00**	.02

Notes. * p < .05, ** p < .001; [a] Degrees of freedom are (1, 1090) for Mathematical ability and Sex, and (3, 1090) for Profile and Profile x Sex, respectively.

In addition to sex-differences in Extraversion (boys were less extraverted than girls), Agreeableness (boys were less agreeable than girls), and Emotional Stability (boys were more emotionally stable than girls) we found a significant difference among the study profiles on Extraversion and Agreeableness, and significant interaction-effects between profile and sex on Emotional Stability and on Autonomy. In the high math ability group, the relationships between profile and respectively Conscientiousness, Emotional Stability, and Autonomy were found not significant as opposed to our findings in the overall student group, possibly due to the smaller sample size. Moreover, the interaction-effect between profile and sex on Emotional Stability had not appeared in the overall student sample. In addition to these differences, Table 5 shows that math ability was significantly related to Extraversion (the higher one's math ability, the lower one's score on Extraversion) and to Conscientiousness (the higher one's math ability, the higher one's score on Conscientiousness) as in the overall student sample.

Similar to the analyses presented in Chapter 4, Helmert contrasts were used to interpret the differences among the profiles (both main effects and interaction-effects). Table 6 shows the contrast estimates.

Table 6 *Contrast estimates of differences among the four study profiles for the "high math ability" group*

			95% confidence interval	
		Contrast estimate	Lower	Upper
Helmert 1: SCIENCE versus HEALTH, ECONOMY, and CULTURE				
	Extraversion[a]	-0.26*	-0.47	-0.06
	Agreeableness	-0.02	-0.24	0.19
	Conscientiousness	0.18	-0.07	0.43
	Emotional Stability	0.05	-0.15	0.25
	Autonomy	0.06	-0.14	0.26
Helmert 2: HEALTH versus ECONOMY and CULTURE				
	Extraversion	-0.10	-0.25	0.05
	Agreeableness	0.09	-0.07	0.25
	Conscientiousness	0.08	-0.10	0.26
	Emotional Stability	0.06	-0.09	0.20
	Autonomy	-0.01	-0.16	0.14
Helmert 3: ECONOMY versus CULTURE				
	Extraversion	0.07	-0.15	0.29
	Agreeableness	-0.27*	-0.49	-0.04
	Conscientiousness	0.10	-0.16	0.37
	Emotional Stability	-0.05	-0.26	0.16
	Autonomy	-0.16	-0.38	0.05

Notes. * $p < .05$; [a] one-tailed test.

The contrast estimates show only two significant differences. Helmert 1 indicates that "high math ability" SCIENCE students significantly differ in their scores on Extraversion from "high math ability" students who chose other study profiles. As in the overall student group, SCIENCE students were more introverted than other students whilst controlling for math ability. The second difference is found in the third Helmert contrast. It indicates that CULTURE students have higher scores on Agreeableness than ECONOMY students. Other differences between the study profiles we found in the overall student sample were not replicated in the high math ability group.

As regards the interaction-effects presented in Table 5 we can conclude the following. We found that SCIENCE boys in our subsample had significantly lower scores on Autonomy than SCIENCE girls in our subsample (contrast estimate -2.05, $p < .001$; 95% confidence interval [-3.25 to -0.84]), however, no sex-differences were observed as regards this factor in the other profiles. The factor-contrast-interaction for the factor Emotional Stability shows that, among all profiles, high math ability boys had higher scores on Emotional Stability (on average) than high math ability girls, yet that the difference between the sexes was more marked among CULTURE students than among students pursuing other study profiles.

Based on these results we can conclude that our findings in the high math ability group are, to a large extent, consistent with our findings in the overall student group presented in Chapter 4. In particular, the result that SCIENCE students were, in general, more introverted than other students was replicated in the subsample.

Nederlandstalige Samenvatting

De in dit proefschrift beschreven studies zijn alle uitgevoerd in de context van geringe deelname van Nederlandse leerlingen aan bètavakken in het voortgezet onderwijs (wiskunde B, scheikunde en natuurkunde) en aan bètastudies in het hoger onderwijs. In Nederland kiezen weinig leerlingen ervoor om hun eindexamen voortgezet onderwijs in het natuur & techniek profiel af te leggen. Dit profiel omvat de vakken wiskunde B, scheikunde en natuurkunde en is verplicht voor het doorstromen naar een bètastudie in het hoger onderwijs. Het doel van deze dissertatie was tweeledig. Het eerste doel was (1) het identificeren van specifieke kenmerken van leerlingen die het natuur & techniek profiel volgen en/of een bètastudie volgen. Meer specifiek waren we geïnteresseerd in mogelijke verschillen tussen bètaleerlingen (in het voortgezet en hoger onderwijs) en niet-bètaleerlingen wat betreft kenmerken zoals capaciteiten, persoonlijkheidskenmerken, studiegedrag en attitudes. Het tweede doel was (2) het identificeren van leerlingen in de niet-bètagroep die, op basis van deze kenmerken, bij het natuur & techniek profiel en/of een bètastudie zouden passen. We hebben daarbij tevens gekeken naar sekseverschillen. Aan de hand van deze twee doelen hebben we zes empirische studies uitgevoerd en gepresenteerd in dit proefschrift. Voor elke studie zijn meerdere onderzoeksvragen en hypothesen geformuleerd die sterk gefundeerd zijn op theoretische inzichten en empirische resultaten van verschillende onderzoekers in het veld. In elke studie zijn grote kwantitatieve datasets gebruikt om de onderzoeksvragen te beantwoorden en de hypothesen te toetsen. We hebben in dit proefschrift gebruik gemaakt van Nederlandse data uit een grootschalig longitudinaal cohort, genaamd "Voortgezet Onderwijs Cohort Leerlingen" (VOCL'99). In dit cohort worden leerlingen vanaf de eerste klas voortgezet onderwijs gevolgd totdat ze het voltijds onderwijs hebben verlaten. De dataset bestaat uit een breed scala aan informatie over de achtergrond en de psychologische kenmerken van de leerlingen. Door het longitudinale karakter van het cohort konden we de leerlingen op meerdere momenten in hun onderwijsloopbaan bestuderen. Ons onderzoeksproject richtte zich op de twee hoogste niveaus van het voortgezet onderwijs (havo en vwo) en de eerste jaren van het hoger onderwijs. De hoofdstukken 2 tot en met 5 hebben betrekking op leerlingen in het voortgezet onderwijs. In deze hoofdstukken hebben we gebruik gemaakt van data die verzameld is tussen 1999 en 2005. De hoofdstukken 6 en 7 hebben betrekking op een subgroep van deze leerlingen, namelijk de leerlingen die na hun eindexamen zijn doorgestroomd naar een studie in het hoger onderwijs. Aanvullende informatie over deze leerlingen is verzameld aan de hand van een vervolgvragenlijst die we in 2008 naar de thuisadressen van de ouders hebben gestuurd.

Deze samenvatting begint met een opsomming van de belangrijkste bevindingen van het proefschrift, waarbij we een beknopte bijdrage van elke studie presenteren evenals onze algemene conclusies. In het daarop volgende discussiegedeelte bespreken we eerst de sterke en zwakke kanten van het onderzoeksproject. Daarna volgt een reflectie op de resultaten van het project en doen we enkele suggesties voor toekomstig onderzoek. Tot slot bespreken we de praktische implicaties van ons onderzoek.

Samenvatting van de resultaten

Schattingen van onderbenut bètatalent

Aan het eind van het derde leerjaar kiezen leerlingen een van de vier mogelijke combinaties van vakken (de profielen) waarin ze eindexamen zullen doen. De vier profielen zijn: natuur & techniek (NT), natuur & gezondheid (NG), economie & maatschappij (EM) en cultuur & maatschappij (CM). Deze verplichte profielkeuze is de eerste mogelijkheid voor leerlingen om bètavakken te laten vallen en daarmee een mogelijke carrière in de bètadiscipline te laten varen. In hoofdstuk 2 zijn we hierop ingegaan door na te gaan hoeveel leerlingen die niet voor NT hadden gekozen (maar in plaats daarvan voor NG, EM of CM) een redelijke kans hadden gehad om het NT eindexamen succesvol af te kunnen ronden, als ze voor dat profiel hadden gekozen. We hebben de gemiddelde score van NT leerlingen op drie wiskundegerelateerde toetsen gebruikt om vast te stellen hoeveel bètatalent er nodig is voor het volgen van NT. Dit gemiddelde is vervolgens gebruikt om te identificeren welke leerlingen uit de andere profielen over voldoende bètatalent beschikken. Deze longitudinale studie omvatte 6.033 havo en vwo leerlingen. Uit het onderzoek bleek dat veel leerlingen een redelijke kans hadden gehad om het NT eindexamen succesvol af te kunnen ronden als ze voor NT hadden gekozen. Naast de NT leerlingen had minstens 20% van de vwo leerlingen in de andere profielen voldoende bètatalent voor het NT profiel. Van de havo leerlingen in de andere profielen was dat 23%. We vonden getalenteerde leerlingen in alle profielen en het waren zowel jongens als meisjes. Ongeveer 1/4 van de jongens en 1/5 van de meisjes in de profielen NG, EM of CM in zowel havo als vwo had NT kunnen kiezen maar heeft dat niet gedaan. Zodoende heeft dus 20% (vwo) en 23% (havo) van de Nederlandse leerlingen in het voortgezet onderwijs zijn of haar bètatalent onderbenut.

Zijn bètaleerlingen nerds?

Hoofdstuk 3 behandelde het stereotype beeld van bètajongens als "nerds". We poogden te ontdekken of bètaleerlingen een bepaald type leerlingen representeerden. Op basis van een literatuurstudie verwachtten we dat: (1) bètaleerlingen lager scoren op de persoonlijkheidsfactor Extraversie dan niet-bètaleerlingen, (2) bètaleerlingen minder sociale contacten hebben dan niet-bètaleerlingen, (3) bètaleerlingen meer tijd besteden aan computeren en andere media dan andere leerlingen, en dat (4) bètaleerlingen minder tijd besteden aan sport, relaties en sociale contacten dan niet-bètaleerlingen. We hebben gebruik gemaakt van geretourneerde vragenlijsten van 1.812 NT jongens in havo en vwo. In lijn met onze verwachtingen vonden we dat deze jongens gemiddeld lager scoorden op de persoonlijkheidsfactor Extraversie dan andere jongens en dat zij gemiddeld minder vriendinnen hadden dan andere jongens. Dit laatste resultaat vonden we alleen voor vwo leerlingen. Bovendien vonden we geen verschillen tussen de groepen wat betreft het aantal vrienden. Daarnaast konden we de derde hypothese niet bevestigen. Wat betreft de vierde hypothese vonden we dat bètajongens inderdaad minder tijd besteedden aan sport, relaties en sociale contacten dan andere jongens, maar dat de verschillen tussen de groepen (zeer) klein waren. Zowel de scores op de persoonlijkheidsfactor Extraversie als de score op het aantal vriendinnen (in vwo) droegen bij aan de voorspelling of leerlingen NT volgden of een ander profiel. Alles samengenomen kunnen we echter stellen dat het stereotyperen van bètajongens als nerds grotendeels ongegrond is.

De match tussen persoonlijkheid en profielkeuze

De derde studie (hoofdstuk 4) verkende de relatie tussen persoonlijkheidskenmerken en de profielkeuze van leerlingen in het voortgezet onderwijs. De hoofdvraag was: “Zijn er verschillen in persoonlijkheidskenmerken tussen leerlingen die verschillende profielen volgen?” Zowel jongens als meisjes werden onderzocht. We hebben gebruik gemaakt van de Five-Factor Personality Inventory (FFPI) van Hendriks, Hofstee en De Raad (1999a) om de persoonlijkheidskenmerken van 3.992 derdejaars leerlingen te meten. We vonden significante verschillen tussen de leerlinggroepen (NT, NG, EM en CM) met betrekking tot alle vijf persoonlijkheidsfactoren (Extraversie, Mildheid, Ordelijkheid, Emotionele Stabiliteit en Autonomie). Over het algemeen bleek dat de natuurprofielen de wat introvertere leerlingen aantrokken, terwijl de maatschappijprofielen de wat extrovertere leerlingen aantrokken. Zoals verwacht vonden we een negatieve samenhang tussen Extraversie en het kiezen van NT, ook als we controleerden voor bètatalent. Daarnaast vonden we dat naarmate het gekozen profiel meer bètageoriënteerd was, de scores op Ordelijkheid en Emotionele Stabiliteit hoger werden. Aanvullend vonden we dat CM leerlingen gemiddeld hoger scoorden op Mildheid dan EM leerlingen. Tot slot bleek dat NT jongens en EM jongens gemiddeld lagere scores hadden op de factor Autonomie dan meisjes in deze profielen, terwijl de scores van CM meisjes op deze factor lager waren dan de scores van CM jongens. Alles bij elkaar genomen vonden we ondersteuning voor Holland’s theorie (1997) dat interesses en in ons geval dus de profielkeuzes van leerlingen samenhangen met hun persoonlijkheid.

Voorwaarden voor succes in het natuur & techniek profiel

In hoofdstuk 5 hebben we onderzocht aan welke voorwaarden leerlingen moeten voldoen om het eindexamen voor wiskunde B, scheikunde en natuurkunde succesvol af te ronden. In het eerste deel van deze studie hebben we net als in hoofdstuk 2 gekeken naar (sekse)verschillen in bètatalent tussen leerlingen die verschillende profielen volgen. Dit gedeelte van de studie omvatte 6.033 leerlingen. De resultaten lieten zien dat NT leerlingen gemiddeld hoger scoorden op onze bètatalent variabele dan andere leerlingen en dat jongens gemiddeld hoger scoorden dan meisjes. Bovendien werd de hypothese bevestigd dat NT meisjes hoger scoorden dan NT jongens op deze variabele, terwijl meisjes in andere profielen juist lager scoorden dan jongens in die profielen. Alleen de meisjes met een hoge score op bètatalent hadden gekozen voor NT. Voor het tweede deel van deze studie werden 720 leerlingen geselecteerd die eindexamen hadden gedaan in het NT profiel. In de onderzoeksliteratuur worden cognitieve capaciteiten, prestatiemotivatie en huiswerktijd genoemd als voorspellers van leerlingprestaties (bijvoorbeeld gemiddeld eindexamencijfer). Om de kennis op dit gebied te verbreden hebben we deze bevindingen gerepliceerd binnen de NT groep en hebben we de relaties tussen bètatalent, academische prestatiemotivatie (APM) en huiswerktijd (HWT) bij het verklaren van het gemiddelde eindexamencijfer voor de bètavakken (wiskunde B, natuurkunde en scheikunde) proberen te verduidelijken. Voor de metingen van APM en HWT hebben we gebruik gemaakt van een vragenlijst. Regressieanalyses lieten zien dat bètatalent en APM beiden een afzonderlijke bijdrage leverden aan de verklaring van het gemiddelde eindexamencijfer voor de bètavakken. In lijn met onze verwachtingen vonden we significant positieve effecten van wiskunde talent en APM op het gemiddelde eindexamencijfer voor bètavakken van NT leerlingen. Het verwachtte positieve effect van HWT op het gemiddelde eindexamencijfer op deze vakken kon niet worden bevestigd. Dit was ook het geval voor mogelijke mediërende en modererende effecten van bètatalent, APM en HWT op dit cijfer. Tegen de verwachtingen in vonden we een suppressie-effect; de relatie tussen APM en het gemiddelde eindexamencijfer voor de bètavakken was sterker voor leerlingen die weinig tijd aan hun huiswerk besteedden dan voor leerlingen die veel tijd aan hun huiswerk besteedden. Het belangrijkste resultaat dat we vonden was echter dat APM een even grote bijdrage leverde aan de voorspelling van het gemiddelde eindexamencijfer voor bètavakken van de NT leerlingen als de variabele bètatalent.

Stereotypen over en percepties van bètastudies

In hoofdstuk 6 werd duidelijk dat een aanzienlijk deel van de NT leerlingen niet doorgestroomd was naar een bètastudie in het hoger onderwijs. In plaats daarvan hadden zij een andere, niet-bètastudie gekozen en daardoor hun bètatalent niet benut. In deze vijfde studie hebben we onderzocht waarom deze talentvolle leerlingen (vanaf hier studenten) niet voor een bètastudie hebben gekozen. Hiertoe hebben we de attitudes ten aanzien van bètastudies onderzocht van studenten die wel en studenten die geen bètastudie hadden gekozen (en daardoor wel of geen ervaring hebben met bètastudies in het hoger onderwijs). We verwezen naar "percepties" voor de attitudes van bètastudenten ten aanzien van bètastudies (gebaseerd op ervaring) en naar "stereotypen" voor de attitudes van niet-bètastudenten ten aanzien van bètastudies (niet gebaseerd op ervaring). De vergelijking van stereotypen met percepties liet zien of de stereotypen in enige mate overeenkwamen met de realiteit (zoals gepercipieerd door bètastudenten). We vergeleken bijvoorbeeld de stereotypen over de beroepsperspectieven van technische studies van niet-bètastudenten met de percepties over deze beroepsperspectieven van studenten die zelf een technische studie volgden. Het onderzoek betrof 1.935 studenten in het hoger onderwijs (grotendeels tweede- en derdejaarsstudenten). In het onderzoek werden zes hypothesen getoetst. Eerst hebben we gekeken naar de stereotypen van niet-bètastudenten over exacte en technische studies. De analyses bevestigden onze verwachting dat bij deze groep studenten de stereotypen over technische studies positiever waren dan de stereotypen over exacte studies (bv. met betrekking tot carrièreperspectieven en de verwachtte smalle oriëntatie van exacte studies). Daarnaast vonden we dat de stereotypen van niet-bètastudenten die het NT profiel gevolgd hadden over het algemeen positiever waren dan de stereotypen van niet-bètastudenten die NG, EM of CM hadden gevolgd. Zoals verwacht vonden we enkele interactie-effecten tussen gekozen profiel (NT of niet-NT) en sekse op de stereotypen van niet-bètastudenten over exacte en technische studies. De stereotypen over exacte en technische studies van NT meisjes waren over het algemeen positiever dan die van NT jongens en dan die van leerlingen die een ander profiel gevolgd hadden. Toch hadden zij geen bètastudie gekozen in het hoger onderwijs. Ten tweede hebben we gekeken naar de percepties die studenten van hun eigen gekozen studie hebben (exact, technisch of anders). De resultaten lieten zien dat de percepties die bètastudenten van hun eigen studie (exact of technisch) hadden nauwelijks afweken van de percepties die niet-bètastudenten hadden van hun eigen studie, op een aantal kleine uitzonderingen na. Ten derde hebben we de stereotypen van niet-bètastudenten en de percepties van bètastudenten met elkaar vergeleken. Een belangrijk resultaat was dat niet-bètastudenten een minder gevarieerde inhoud verwachtten van exacte studies dan de mate van gevarieerdheid die door bètastudenten werd gepercipieerd. Daarnaast vonden we dat veel niet-bètastudenten verwachtten dat een bètastudie niet bij hen zou passen (bv. passend in het algemeen, verwachtte prestaties), terwijl bètastudenten hun studie wel als passend ervoeren. De stereotypen over en percepties van de inhoud van technische studies kwam grotendeels overeen. Tot slot hebben we een aantal complexe interactie-effecten getoetst. Voor een deel bevestigden de resultaten onze verwachting dat bij de bètastudenten degenen die niet het NT profiel hadden gevolgd positievere percepties hadden van hun eigen gekozen exacte of technische studie dan degenen die wel NT hadden gevolgd, terwijl bij de niet-bètastudenten degenen die niet NT hadden gevolgd minder positieve stereotypen over exacte en technische studies hadden dan degenen die wel het NT profiel hadden gevolgd. Daarentegen vonden we geen ondersteuning voor onze hypothese dat de verschillen tussen stereotypen over en percepties van bètastudies verschilden tussen de seksen.

Waarom sommige leerlingen met toegang tot bètastudies niet kozen voor bèta

In de laatste studie (hoofdstuk 7) hebben we onderzocht waarom sommige leerlingen met toegang tot bètastudies niet hebben gekozen voor een bètastudie in het hoger onderwijs, ondanks hun eerdere interesse in bètavakken in het voortgezet onderwijs. Deze studie was gebaseerd op "multi-attribute utility theory", gebruik makend van een benadering gerelateerd aan de theorie van beredeneerd gedrag (Fishbein & Ajzen, 2010). De studie omvatte 477 studenten die examen hadden gedaan in het NT of NG profiel maar daaropvolgend geen bètastudie hadden gekozen. De attitudes van deze studenten ten aanzien van bètastudies zijn vergeleken met hun attitudes ten aanzien van hun huidige (niet-bèta) studie. Zoals verwacht hadden de meeste niet-bètastudenten de best passende optie gekozen voor wat betreft hun attitudes. Echter een op de tien niet-bètastudenten, vooral NT meisjes, had een positievere attitude ten aanzien van bètastudies dan ten aanzien van de gekozen studie (vooral met betrekking tot keuzemogelijkheden, inhoud en prestaties). Aanvullend vonden we dat de attitudes ten aanzien van technische studies bij de niet-bètastudenten positiever waren dan hun attitudes ten aanzien van exacte studies. De hypothese dat belangrijke anderen (bv. ouders, peers of mensen van scholen) deze studenten geadviseerd hadden om geen bètastudie te kiezen werd in onze data niet bevestigd.

Conclusies

Samenvattend kunnen we stellen dat de uitgevoerde studies bruikbare resultaten hebben opgeleverd voor onze hoofddoelstellingen. We hebben verschillende specifieke kenmerken van leerlingen die het NT profiel volgen en/of een bètastudie volgen geïdentificeerd met betrekking tot capaciteiten, persoonlijkheid, studiegedrag en attitudes (ons eerste doel). Daarnaast hebben we vele leerlingen kunnen identificeren die wat betreft de genoemde kenmerken zouden passen bij het NT profiel en/of een bètastudie (ons tweede doel). Wat betreft capaciteiten vonden we dat NT leerlingen over het algemeen hoger scoorden op bètatalent dan andere leerlingen. De gemiddelde scores op bètatalent namen geleidelijk af naarmate het gekozen profiel minder bètageoriënteerd was. Desondanks vonden we dat naast de leerlingen die al het NT profiel volgden ongeveer 1/4 van de niet-NT jongens en bijna 1/5 van de niet-NT meisjes voldoende bètatalent hadden om NT te volgen. Van de niet-NT leerlingen scoorde minstens 20% van de vwo leerlingen en 23% van de havo leerlingen even hoog of hoger op bètatalent dan de gemiddelde NT leerling, met andere woorden, zij hadden hun bètatalent onderbenut. Hoewel bètatalent belangrijk is, lieten de resultaten van hoofdstuk 5 echter zien dat academische prestatiemotivatie een even grote bijdrage leverde aan de hoogte van het gemiddelde eindexamencijfer voor wiskunde B, scheikunde en natuurkunde.

Wat betreft persoonlijkheidskenmerken vonden we dat over het geheel genomen NT leerlingen niet veel verschilden van andere leerlingen. Uit onze resultaten kwamen slechts enkele specifieke kenmerken naar voren. Over het algemeen bleken NT leerlingen wat minder extravert dan andere leerlingen, maar overige minder positieve kenmerken (bv. kenmerken die geassocieerd worden met het nerd stereotype) werden nauwelijks bevestigd in de analyses. Bovendien vonden we ook introvertere leerlingen bij de andere profielen. Hoewel de resultaten van hoofdstuk 4 onze verwachting bevestigde dat de profielkeuze samenhangt met persoonlijkheidskenmerken van leerlingen, kunnen we stellen dat op basis van deze resultaten een vaststaand beeld van typische bètaleerlingen grotendeels ongegrond is. Wat betreft deze specifieke kenmerken hadden vele andere leerlingen (zowel jongens als meisjes) bij het NT profiel gepast naast de groep die al voor dat profiel had gekozen.

In onze studies op het gebied van het hoger onderwijs bleken enkele verschillen in attitudes ten aanzien van bètastudies. We vonden bijvoorbeeld dat veel niet-bètastudenten minder positieve stereotypen hadden over exacte studies en dat sommige niet-bètameisjes die examen hadden gedaan in het NT profiel juist vrij positief waren over technische studies. De minder positieve stereotypen van niet-bètastudenten over bètastudies kwamen vaak niet overeen met de werkelijkheid zoals die gepercipieerd werd door studenten die zelf een exacte of technische studie volgden. Daarnaast vonden we dat wat betreft hun attitudes een op de tien niet-bètastudenten, vooral NT meisjes, vermoedelijk beter bij een bètastudie zou passen dan bij de huidige gekozen studie. Ook dit is een voorbeeld van onderbenut bètatalent.

Discussie

Sterke en zwakke kanten van het onderzoeksproject

In elk hoofdstuk van dit proefschrift is een apart discussiegedeelte opgenomen waarin de sterke en zwakke kanten van de betreffende studie worden besproken. De hier aangedragen punten hebben daarom vooral betrekking op het totale onderzoeksproject.

Het sterkste punt van deze dissertatie is in onze ogen de dataset die we gebruikt hebben voor het uitvoeren van de studies. Door de grootschalige dataset van VOCL'99 beschikten we over waardevolle informatie om zowel in het voortgezet onderwijs als in de eerste jaren van het hoger onderwijs analyses uit te voeren. We konden op verschillende momenten in de tijd het onderbenutte bètatalent bestuderen, doordat we dezelfde leerlingen meerdere jaren konden volgen. Helaas was de dataset waarvan we gebruik konden maken in veel gevallen incompleet. Gedurende de voortgang van de dataverzameling groeide de hoeveelheid missende data, voornamelijk door een groeiende non-respons op de vragenlijsten die in het cohort gebruikt werden. Vooral de respons van studenten in het hoger onderwijs op onze vervolgvragenlijst was teleurstellend. Pogingen om de respons te verhogen faalden (Rekers-Mombarg, Korpershoek, Kuyper, & Van der Werf, 2010). Ofschoon we overtuigd zijn van het nut van modelgebaseerde imputatie om het aantal cases te verhogen dat in de analyses gebruikt kan worden, hebben we deze benadering niet gebruikt in dit onderzoeksproject. Met name de non-respons groep binnen onze steekproef in het hoger onderwijs was groot. Van de meeste van deze studenten weten we niet waarom ze niet op de vragenlijst gerespondeerd hebben. Een aanzienlijk deel van de studenten heeft de vragenlijst niet ontvangen, andere studenten hebben bewust gekozen om niet te responderen. De vragenlijsten zijn verstuurd naar de thuisadressen van de ouders, terwijl studenten vaak verhuizen en/of niet altijd hun post lezen. Hieruit volgend konden we dus niet vaststellen of deze data missing completely at random (volledig willekeurig), missing at random (willekeurig) of missing not at random (onwillekeurig) misten. Om deze reden hebben we ervoor gekozen non-respons analyses uit te voeren op de datasets die we gebruikt hebben in de studies. Over het algemeen lieten deze analyses weinig verschillen zien tussen de respons en non-respons groepen wat betreft de achtergrondkenmerken van de leerlingen en studenten. Bovendien waren de overgebleven datasets nog tamelijk groot. In onze optiek is onze database daarom voldoende geschikt om de gevonden resultaten te generaliseren naar de havo en vwo leerlingenpopulatie in Nederland. Om de resultaten te bevestigen stellen we evenwel voor de studies te repliceren, in het bijzonder de studies die we in het hoger onderwijs hebben uitgevoerd.

Het tweede sterke punt van de in dit proefschrift gepresenteerde studies is dat we inzicht hebben gekregen in de doorgaans complexe relaties tussen determinanten van keuzegedrag van leerlingen. Dat er in het Nederlandse voortgezet en hoger onderwijs veel onderbenut bètatalent beschikbaar is hebben we met empirische gegevens kunnen ondersteunen. Bovendien hebben we op innovatieve wijze leerlingen geïdentificeerd die bij het NT profiel en/of een bètastudie zouden passen. In de hoofdstukken 2 - 5 hebben we specifieke kenmerken van NT leerlingen gebruikt als indicator voor de "voorwaarden" waaraan leerlingen moeten voldoen om NT te kiezen in het voortgezet onderwijs. In deze studies hebben we specifieke kenmerken van NT leerlingen (bv. hun bètatalent) vergeleken met de kenmerken van NG, EM en CM leerlingen. Op eenzelfde wijze hebben we in de studies die we hebben beschreven in de hoofdstukken 6 en 7 de attitudes en percepties die studenten hebben van bètastudies in het hoger onderwijs gebruikt om niet-bètastudenten te identificeren die bij een bètageoriënteerde onderwijsloopbaan zouden passen. Het maken van deze vergelijkingen bleek een bruikbare methode voor het identificeren van onderbenut bètatalent in het voortgezet en hoger onderwijs in Nederland.

Het derde sterke punt dat we hier willen noemen betreft de procedure die we in hoofdstuk 7 hebben toegepast. Om de studiekeuze van leerlingen beter te begrijpen hebben we gebruik gemaakt van enkele basisprincipes uit de beslissingstheorie. De betreffende studie was gebaseerd op "multi-attribute utility theory" (MAUT), gebruik makend van een benadering gerelateerd aan de theorie van beredeneerd gedrag ("Theory of Reasoned Action" [TRA], Fishbein & Ajzen, 2010). We hebben enkele constructen uit TRA gebruikt om bij de niet-bètastudenten de attitudes ten aanzien van bètastudies in het hoger onderwijs te meten. Volgend uit MAUT hebben we drie alternatieven geëvalueerd (m.a.w. drie disciplines die de studenten hadden kunnen kiezen) voor elk individu. We hebben voor alle studenten de "optimale" keuze opgespoord wat betreft hun attitudes ten aanzien van de drie alternatieven. Deze procedure, namelijk de combinatie van MAUT en TRA, is nieuw in het onderzoeksveld. Het bleek een waardevolle en bruikbare benadering om te ontdekken waarom sommige getalenteerde leerlingen ondanks hun talent niet hadden gekozen voor een bètastudie in het hoger onderwijs.

Een mogelijke zwakte van het onderzoeksproject die we hier willen bespreken heeft te maken met het construct bètatalent. In de empirische studies beschreven in de hoofdstukken 2 tot en met 5 hebben we de wiskundevaardigheid van leerlingen gebruikt als indicator voor bètatalent. Deze variabele was gebaseerd op drie wiskundegerelateerde toetsen waarvan we stelden dat zij "in essentie een combinatie representeren van nature (capaciteit) en nurture (prestaties)". Hoewel cognitieve capaciteit verreweg de beste voorspeller is van schoolprestaties (Gagné & St Père, 2002) is het moeilijk om de constructen capaciteit en prestaties te onderscheiden wanneer personen opgeleid zijn (Carroll & Horn, 1981). Wij denken dat onze gecombineerde score, gebaseerd op zowel capaciteit als prestaties, de betrouwbaarheid en validiteit van onze bètatalent variabele heeft vergroot ten opzichte van het gebruik van een enkele prestatietoets. Helaas valt een uitgebreide discussie over welk construct het beste gebruikt kan worden buiten het bestek van dit proefschrift. Desalniettemin onderschrijven we dat wiskundevaardigheid slechts een beperkte indicator is van bètatalent. De voorspellende waarde van ons construct op het gemiddelde eindexamencijfer voor wiskunde B, scheikunde en natuurkunde is bescheiden. We komen hier in de volgende paragraaf nog op terug.

Suggesties voor toekomstig onderzoek

In deze sectie reflecteren we op enkele hoofdconclusies van de gepresenteerde studies. Volgend uit onze resultaten doen we een aantal suggesties voor onderzoek waar onderwijsonderzoekers zich in de toekomst op kunnen richten.

In hoofdstuk 2 hebben we onderzocht hoeveel leerlingen die niet voor NT hadden gekozen (maar in plaats daarvan voor NG, EM of CM) een redelijke kans hadden gehad om het NT eindexamen succesvol af te kunnen ronden, als ze voor dat profiel hadden gekozen. We baseerden ons daarbij op hun bètatalent, gebaseerd op hun prestaties op drie wiskundegerelateerde toetsen. Zoals we in hoofdstuk 2 al aanstipten stonden ons geen curriculumonafhankelijke toetsen voor scheikunde en natuurkunde ter beschikking, terwijl het aannemelijk is dat bètatalent meer omvat dan alleen wiskundetalent. Onze suggestie is daarom hier aandacht aan te besteden in toekomstige studies gericht op het meten van onderbenut bètatalent. We achten het echter belangrijk om eerst meer te weten over de exacte vereisten die nodig zijn voor een succesvolle bètacarrière. Deze vereisten zijn veelal onduidelijk, en daarom vinden we dat daar eerst meer onderwijskundig onderzoek naar gedaan dient te worden. Het is onduidelijk welke variabelen goede voorspellers zijn van succes in bètastudies en op de arbeidsmarkt. Over het algemeen is het voldoen aan de toelatingscriteria van bètastudies voldoende voor een succesvolle bètacarrière, omdat eerdere successen doorgaans een positief effect hebben op succes in de toekomst in eenzelfde domein. Maar hoe belangrijk zijn eindexamencijfers in vergelijking met interesse in bètagerelateerde onderwerpen en motivatie om hard te werken voor complexe opdrachten (zie hoofdstuk 5)? Aanvullend stellen we voor om extra aandacht te besteden aan sekseverschillen aangaande deze onderwerpen. In het voortgezet onderwijs hebben NT meisjes gemiddeld hogere scores op bètatalent dan NT jongens. Deze onevenwichtigheid is een belangrijk aandachtspunt, aangezien deze verschillen zich voort zouden kunnen zetten in bètastudies in het hoger onderwijs. Inzicht in deze gegevens kan bijdragen aan het begrip welke studenten goed bij een bètastudie zouden passen. Deze kennis is nodig om het onderhavige onderzoek voort te kunnen zetten.

Aanvullend stellen we voor studenten langere tijd te volgen, zowel tijdens de studie als daarna. De langere looptijd van het onderzoek kan inzicht geven in de definitieve onderbenutting van bètatalent. Studenten die een bètastudie hebben gevolgd kiezen wellicht alsnog voor een andere studierichting wanneer ze de arbeidsmarkt opgaan. Daarnaast kiezen sommige studenten die in een eerder stadium geen bètageoriënteerde onderwijsloopbaan volgden wellicht toch voor een bètageoriënteerde carrière, bijvoorbeeld met behulp van aanvullende cursussen die ze buiten het reguliere onderwijs hebben gevolgd. Inzicht in deze participatiecijfers geven een preciezere langetermijnschatting van onderbenut bètatalent.

In de hoofdstukken 3 en 4 hebben we verschillende relaties gevonden tussen de persoonlijkheidskenmerken en profielkeuzes van leerlingen in het voortgezet onderwijs. Op basis van onze resultaten kunnen we aannemen dat introverte leerlingen beter bij een bètageoriënteerde richting (bv. het NT profiel) passen dan extraverte leerlingen. Derhalve zou het stimuleren van introverte leerlingen om het NT profiel te kiezen effectiever kunnen zijn dan het proberen te overtuigen van extraverte leerlingen om een bètaprofiel te kiezen. Echter, we hebben in deze studie niet onderzocht wat de daadwerkelijke invloed is van persoonlijkheidskenmerken op de profielkeuze van leerlingen. We stellen daarom voor in verklarende onderwijskeuzemodellen (bv. Van Langen, 2005) persoonlijkheidskenmerken als mogelijke verklarende factor mee te nemen naast de gebruikelijke factoren zoals capaciteiten, achtergrondfactoren en attitudes. Op basis van onze resultaten verwachten we dat persoonlijkheidskenmerken wellicht een bijdrage kunnen leveren aan het verklaren van keuzegedrag van leerlingen in het onderwijs. Bijkomend lijkt het ons zinvol na te gaan of de persoonlijkheidsverschillen die we gevonden hebben in het voortgezet onderwijs ook relevant zijn in het hoger onderwijs. Zijn bètastudenten bijvoorbeeld gemiddeld minder extravert dan niet-bètastudenten?

De resultaten van hoofdstuk 6 gaven inzicht in de attitudes van bètagetalenteerde studenten ten aanzien van bètastudies in het hoger onderwijs. Binnen de groep niet-bètastudenten hadden NT leerlingen doorgaans positievere stereotypen over bètastudies dan niet-NT leerlingen. Op basis hiervan kunnen we argumenteren dat meer ervaring met wiskundige en bètagerelateerde onderwerpen een positief effect kan hebben op de attitudes ten aanzien van bètastudies en dus een verhoogde instroom in bètastudies. Meer ervaring zou opgedaan kunnen worden door bijvoorbeeld een jaar extra wiskunde B, scheikunde en natuurkunde te volgen in het voortgezet onderwijs. Als we bètatalent opvatten als developing expertise ("ontwikkelende bekwaamheid", Sternberg, 1999), dan is de mogelijkheid om bètavakken te laten vallen aan het eind van de derde klas in het huidige Nederlandse onderwijssysteem aanvechtbaar. Meer ervaring met bètageoriënteerde onderwerpen kan gunstig zijn voor de onderwijsloopbaan van leerlingen. Het is de moeite waard uit te zoeken wat een jaar extra wiskundeonderwijs voor invloed heeft op het zelfvertrouwen van leerlingen in hun wiskundevaardigheid en vervolgens op hun profielkeuze in het voortgezet onderwijs. Het is evident dat hiervoor grootschalig longitudinaal onderzoek in een experimentele setting nodig is.

Bijkomend stellen we voor de invloed van bètatalent op diverse onderwijsuitkomsten te vergelijken met de invloed van andere talenten (bv. taaltalent). Wat is bijvoorbeeld het effect van deze talenten op de profielkeuze van leerlingen (bv. Uerz, Dekkers, & Beguin, 2004), de eindexamenprestaties, de studiekeuze en de voortgang tijdens de studie in het hoger onderwijs? Met deze vragen kunnen we de voordelen van het hebben van bepaalde talenten (bv. bètatalent of taaltalent) voor bepaalde onderwijsloopbanen bestuderen. Uerz en anderen (2004) hebben bijvoorbeeld onderzocht wat het effect is van goed zijn in wiskunde ten opzichte van goed zijn in taal ("comparative advantage"), dus het verschil tussen wiskunde- en taalscores op prestatietoetsen, op het aantal gekozen bètavakken voor het eindexamen. Zij concludeerden dat het absolute verschil tussen wiskunde- en taalvaardigheid een aanzienlijke bijdrage leverde aan de keuze van het aantal bètavakken. Leerlingen met relatief hogere wiskundescores dan taalscores kozen meer bètavakken dan leerlingen waarbij het verschil tussen wiskunde en taal kleiner was (Uerz e.a., 2004, p.180).

We doen de suggestie deze analyse te herhalen in de huidige situatie waarin leerlingen een van de vier profielen moeten kiezen.

Een ander punt waar we hier aandacht aan willen besteden is het bestuderen van het effect van belangrijke anderen (bv. ouders) op het keuzegedrag van leerlingen. In hoofdstuk 7 hebben we retrospectieve vragen gesteld om dit effect te meten. We hebben de studenten in onze vervolgvragenlijst gevraagd aan te geven of en in welke mate ze zich bij hun studiekeuze hebben laten beïnvloeden door belangrijke anderen. Omdat de studenten de keuze minstens twee jaar voor de dataverzameling gemaakt hebben kan het zijn dat zij de invloed van anderen achteraf onderschatten, bijvoorbeeld doordat studenten (onbewust) achteraf hun eigen motivatie voor de huidige studie verhogen. Cognitieve dissonantietheorie (Festinger, 1957) stelt dat mensen inconsistentie tussen negatieve kenmerken van de gekozen optie en de positieve kenmerken van de niet gekozen optie proberen te reduceren om zo hun eigen motivatie voor de gemaakte keuze te verhogen. Mensen zijn geneigd om achteraf bezien hun gemaakte keuzes te rechtvaardigen, dus om de gebleken dissonantie te reduceren. Aangezien onze vragen betrekking hadden op een al eerder gemaakte keuze is het aannemelijk dat studenten achteraf bezien denken dat ze de keuze in meer of mindere mate onafhankelijk van hun sociale omgeving hebben gemaakt. Het is echter ook mogelijk dat studenten de invloed van de sociale omgeving hebben overschat; bijvoorbeeld, studenten die spijt hebben van hun studiekeuze geven daar liever anderen de schuld van. Zo proberen ze spijt achteraf te voorkomen ("post-decisional regret", zie bv. Bell, 1982), wat in ons geval betekent dat ze de invloed van belangrijke anderen kunnen overschatten. Door anderen de schuld te geven wordt dissonantie vermeden. We opperen de idee om het model zoals voorgesteld door Fishbein en Ajzen (2010) toe te passen op de studiekeuze van studenten, om zo het effect van de subjectieve norm (de sociale invloed) te kunnen onderzoeken. In hun geïntegreerde model zijn zowel descriptieve als "injunctieve" normatieve overtuigingen verbonden met de subjectieve norm, wat vervolgens weer in verbinding staat met de intentie van mensen om bepaald gedrag te vertonen. Dit betekent dat naast de perceptie van wat anderen vinden wat een persoon moet doen ook het daadwerkelijke gedrag van die belangrijke anderen in de verklarende keuzemodellen moet worden opgenomen. Aangezien een derde van de studenten in het hoger onderwijs aangegeven heeft dat ze zich bij hun keuze door ouders, mensen van school en/of peers hebben laten beïnvloeden (zie hoofdstuk 7) is sociale invloed wellicht een relevante factor voor het keuzegedrag van studenten. Het vernieuwde model van Fishbein en Ajzen (2010) lijkt een bruikbaar hulpmiddel om het effect van sociale invloed op studiekeuzegedrag te onderzoeken, omdat het model minder last heeft van de problemen die het stellen van retrospectieve vragen met zich mee brengt, maar bovenal omdat het model een accurater beeld kan geven van de invloed van belangrijke anderen op de studiekeuze.

Gerelateerd aan het voorgaande raden we aan de benadering beschreven in hoofdstuk 7 meer in detail uit te werken. Eenzelfde procedure zou gebruikt kunnen worden voor het analyseren van profielkeuzes in het voortgezet onderwijs. De attitude constructen uit TRA kunnen dan toegepast worden om bij de leerlingen de attitudes ten aanzien van de vier alternatieven (NT, NG, EM en CM) te meten. We kunnen dan net als in het onderhavige onderzoek de "optimale" keuze bepalen wat betreft de attitudes van de leerlingen en deze vergelijken met de daadwerkelijk gemaakte keuze met behulp van de utiliteitsscores voor elk alternatief. Het voorgestelde onderzoek kan bijdragen aan onze conclusie dat het combineren van MAUT met de meer specifieke TRA modellen waardevolle inzichten geeft in het keuzegedrag van leerlingen.

Praktische aanbevelingen

De grootste bijdrage die dit onderzoek levert aan de onderwijspraktijk is de aanbeveling voor mensen in het onderwijsveld om bij het adviseren van leerlingen naast de meer subjectieve ideeën over de geschiktheid voor bepaalde schoolvakken of studies ook objectieve prestatiemetingen te gebruiken. Op basis van onze resultaten veronderstellen we dat curriculumonafhankelijke toetsen in (in ieder geval) wiskunde, scheikunde en natuurkunde aan het eind van de derde klas de instroom in het NT profiel en vervolgens de doorstroom naar bètastudies in het hoger onderwijs kan vergroten. Met name meisjes zouden profijt kunnen hebben van deze curriculumonafhankelijke toetsen. Weinig meisjes kiezen voor het NT profiel ook al hebben ze voldoende bètatalent, deels omdat meisjes doorgaans minder zelfvertrouwen hebben in hun wiskundevaardigheden (bv. Crombie e.a., 2005; Van Langen, 2005). Aangezien rapportcijfers een weergave kunnen zijn van zowel prestaties als inzet, zijn objectieve prestatietoetsen in onze ogen een zeer geschikte aanvulling voor een dergelijk belangrijk keuzemoment. De toetsresultaten zouden deel uit moeten maken van een standaardpakket van loopbaanadviezen dat leerlingen op school krijgen van hun docenten en/of mentor.

Gegeven het feit dat er behoefte is aan een hogere instroom van leerlingen in bètageoriënteerde loopbanen stellen we voor in plaats van vier aparte profielen twee brede profielen te introduceren. Daarbij zouden NT en NG gecombineerd kunnen worden tot een breed bètaprofiel en EM en CM tot een breed maatschappijprofiel (zie ook Korpershoek, Kuyper, & Van der Werf, 2007). Op deze manier krijgen leerlingen een breed scala aan schoolvakken voorgeschoteld en worden de leerlingen voorbereid op een verscheidenheid aan studies in het hoger onderwijs. Ondanks dat de profielen in eerste instantie werden geïntroduceerd om leerlingen een eenduidige voorbereiding te geven voor specifieke studies in het hoger onderwijs met herkenbare en coherente studieprogramma's heeft de invoering van de profielen de gewenste hogere bèta-instroom niet kunnen verwezenlijken (bv. Van Langen, Rekers-Mombarg, & Dekkers, 2008). Men verwachtte dat het invoeren van de profielen de seksespecifieke vakkenkeuze zou verminderen, maar het tegenovergestelde is gebeurd. Hoewel het aantal meisjes dat kiest voor NT de laatste jaren is gestegen (Van Langen & Vierke, 2009), voldoen in Nederland nog steeds weinig leerlingen (vooral meisjes) aan de toelatingscriteria voor bètastudies. Een breed-georiënteerd vakkenpakket geeft leerlingen de kans hun capaciteiten verder te ontwikkelen in bètageoriënteerde onderwerpen (zie ook Sternberg, 1999). We denken dat een systeem waarin twee brede profielen worden aangeboden de interesse van leerlingen in bètastudies kan verhogen. Zoals bleek uit onze resultaten beschikken veel NG leerlingen over voldoende bètatalent om eindexamen te doen in het NT profiel in plaats van het NG profiel. Daarom denken we dat in het voorgestelde systeem meer huidige NG leerlingen een bètastudie in het hoger onderwijs serieus in overweging zouden nemen. Het systeem biedt een brede basis in een breed scala aan bètaonderwerpen, waardoor leerlingen zich eenvoudigweg beter voorbereid zouden voelen om een bètastudie te kunnen volgen. Momenteel kiest slechts een op de vijf NG leerlingen een bètastudie in het hoger onderwijs (CBS, 2010). Daarnaast zijn het ook niet alleen meisjes die seksespecifieke keuzes maken in het onderwijs, hoewel de meisjesproblematiek doorgaans de meeste aandacht krijgt (Lightbody & Siann, 1997). De verdeling van leerlingen over de vier profielen in Nederland (zie Tabel 1 in Appendix A) laat duidelijk zien dat jongens traditiegetrouw kiezen voor economische en bètageoriënteerde profielen. We verwachten dat het voorgestelde systeem met twee brede profielen resulteert in minder seksespecifieke vakkenkeuzes van zowel meisjes als jongens. Sinds de invoering van de profielen in 1998 werken diverse scholen met twee brede profielen, maar lang niet alle scholen bieden deze mogelijkheid aan hun leerlingen. Ondanks het advies van de "Profielcommissie" (Bruning & De Rooy, 2006) en positieve reacties van universiteiten is in de in 2007 ingevoerde vernieuwde profielenstructuur deze structurele aanpassing niet opgenomen. Tot op de dag van vandaag is het onduidelijk welk systeem effectiever is als het gaat om de benutting van bètatalent, de vroege profielkeuze met vier profielen of het systeem met twee brede profielen. Helaas is er nog geen longitudinaal onderzoek geweest waarin effecten van de twee systemen op de profielkeuze en studiekeuze van de leerlingen is onderzocht. In onze ogen zou het invoeren van twee brede profielen de bèta-instroom kunnen verhogen. Uiteraard is uitgebreid onderzoek nodig om effect van deze systemen op keuzegedrag van leerlingen wetenschappelijk vast te stellen.

Vanuit het oogpunt van de leerlingen is het vroege keuzemoment van eindexamenvakken overigens niet zo problematisch. Onderzoek heeft uitgewezen dat leerlingen achteraf bezien nauwelijks voor een ander profiel hadden willen kiezen (Tweede Fase Adviespunt, 2005) en dat leerlingen doorgaans tevreden zijn met hun gemaakte profielkeuze (De Vries & Van der Velden, 2005; Korpershoek, Kuyper, & Van der Werf, 2006). Minder dan 10 procent van de leerlingen in de vijfde klas had achteraf bezien een ander profiel willen kiezen (Korpershoek e.a., 2006). Daarnaast geeft 85 procent van de studenten in het hoger onderwijs aan dat ze achteraf bezien hetzelfde profiel weer hadden gekozen (De Vries & Van der Velden, 2005). In hoofdstuk 7 vonden we dat de meeste studenten de best passende optie hadden gekozen wat betreft hun attitudes ten aanzien van drie alternatieven (namelijk een exacte studie, een technische studie of een andere studie). Bovendien rapporteerde de Inspectie van het Onderwijs (2003) dat leerlingen sinds de invoering van de profielen in 1998 bewuster zijn gaan kiezen.

Tot besluit hebben de studies die in het kader van het hier gepresenteerde onderzoeksproject zijn uitgevoerd hun bijdrage geleverd aan de wetenschappelijke kennis over onderbenut bètatalent in het onderwijs. Het project heeft waardevolle resultaten opgeleverd en we hebben enkele praktische suggesties geopperd om de bèta-instroom te verhogen. Toekomstig onderzoek zal moeten uitwijzen of met de voorgestelde praktische aanbevelingen daadwerkelijk de gewenste effecten bereikt kunnen worden.

Curriculum Vitae

Hanke Korpershoek (1982) attended the Teachers' Training College for Primary Education at the Christelijke Hogeschool Noord-Nederland and Hanzehogeschool Groningen from 1999 to 2002. Moreover, she studied Educational Sciences at the University of Groningen and attained her doctorate degree in 2005. Her doctoral thesis about early drop-out in pre-vocational secondary education was carried out at the Groningen Institute for Educational Research (GION) of the University of Groningen. After her graduation she worked as an educational researcher at GION, working on reports about the longitudinal VOCL'99 cohort study. Subsequently, she started her PhD study at GION in January 2006. During her PhD she was secretary of the special interest group for PhD students of the VOR (Netherlands Educational Research Association) and member of the educational committee ICO (Interuniversity Centre for Educational Research).

Hanke Korpershoek (1982) volgde de PABO aan de Christelijke Hogeschool Noord-Nederland en de Hanzehogeschool Groningen van 1999 tot 2002. Daarna studeerde zij Onderwijskunde aan de Rijksuniversiteit Groningen en behaalde haar doctoraal diploma in 2005. Haar scriptie over zeer vroegtijdig schoolverlaten in het vmbo is uitgevoerd op het Gronings Instituut voor Onderzoek van Onderwijs (GION) van de Rijksuniversiteit Groningen. Na haar afstuderen werkte ze als onderzoeksmedewerker op het GION, waar ze rapporten schreef over het longitudinale VOCL'99 cohort. In januari 2006 begon zij met haar promotieonderzoek, eveneens op het GION. Tijdens haar promotie was ze secretaris van het VOR-Promovendi Overleg (Vereniging voor Onderwijsresearch) en lid van de onderwijscommissie van het ICO (Interuniversitair Centrum voor Onderwijsonderzoek).

References

Advisory Council for Education. (2004). *Hoe kan onderwijs meer betekenen voor jongeren?* [How can education be of more importance for adolescents?]. Den Haag, The Netherlands: Onderwijsraad.

Advisory Council for Education. (2005). *De helft van Nederland hoogopgeleid; talenten optimaal ontwikkelen en benutten* [Half of the Netherlands highly educated; utilizing and developing talents optimally]. Den Haag, The Netherlands: Onderwijsraad.

Advisory Council for Education. (2007). *Presteren naar vermogen* [Perform according to capacity]. Den Haag, The Netherlands: Onderwijsraad.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckman (Eds.), *Action-control: From cognition to behavior* (pp. 11-39). Heidelberg, Germany: Springer.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179-211.

Ajzen, I. (2002). Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior. *Journal of Applied Social Psychology, 32*, 665-683.

Ajzen, I., & Cote, N. G. (2008). Attitudes and the prediction of behavior. In W. D. Crano & R. Prislin (Eds.), *Attitudes and attitude change* (pp. 289-312). New York, USA/London, UK: Psychology Press.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior.* Englewood-Clisffs, NJ: Prentice-Hall.

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology, 22,* 453-474.

Alting, A. (2003). *Nut, vertrouwen, toegankelijkheid. Wat docenten kunnen doen opdat meer meisjes natuurkunde gaan kiezen* [Usefulness, confidence, accessibility. What teachers can do to increase girls' physics choice]. Eindhoven, The Netherlands: Technische Universiteit Eindhoven.

Archer, J., & Freedman, S. (1989). Gender-stereotypic perceptions of academic disciplines. *The British Journal of Educational Psychology, 59,* 306.

Armitage, C. J., & Conner, M. (2001). Efficacy of the theory of planned behaviour: A meta-analytic review. *British Journal of Social Psychology, 40,* 471-499.

Atkinson, J. W., & Reitman, W. (1958). Performance as a function of motive strength and expectancy of goal attainment. In J. W. Atkinson (Ed.), *Motives in fantasy, action and society* (pp. 278-287). Princeton, NJ: Van Nostrand.

Bandura, A. (1986). *Social foundations of thought and action, a social cognitive theory.* Englewood Cliffs, NJ: Prentice-Hall.

Baron-Cohen, S., Bolton, P., Wheelwright, S., Short, L., Mead, G., Smith, A., & Scahill, V. (1998). Autism occurs more often in families of physicists, engineers, and mathematicians. *Autism, 2,* 296-301.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31,* 5-17.

Barrick, M. R., Mount, M. K., & Gupta, R. (2003). Meta-analysis of the relationship between the five-factor model of personality and Holland's occupational types. *Personnel Psychology, 56,* 45-74.

Bell, D. E. (1982). Regret in decision making under uncertainty. *Operations Research, 30,* 961-981.

Bidjerano, T., & Dai, D. Y. (2007). The relationship between the big-five model of personality and self-regulated learning strategies. *Learning and Individual Differences, 17*, 69-81.

Biermans, M., Korteweg, J. A., & van Leeuwen, M. (2004). *De keuze voor bèta/techniek; kwantitatieve analyse van de keuze voor bèta/techniek op basis van TKMST-data* [Choosing science/technology; quantitative analysis of science/technology choice using TKMST-data]. Amsterdam, The Netherlands: SEO.

Boone, C., Van Olffen, W., & Roijakkers, N. (2004). Selection on the road to a career: Evidence of personality sorting in educational choice. *Journal of Career Development, 31,* 61-78.

Bruning, L., & de Rooy, P. (2006). *Bruggen tussen natuur en maatschappij: Ontwerpadvies* [Bridges across science and society]. Enschede, The Netherlands: SLO.

Busato, V. V., Prins, F. J., Elshout, J. J., & Hamaker, C. (1999). The relations between learning styles, the Big-Five personality traits and achievement in higher education. *Personality and Individual Differences, 26*, 129-140.

Butler, M. B. (1999). Factors associated with students' intentions to engage in science learning activities. *Journal of Research in Science Teaching, 36,* 455-473.

Callahan, K., & Rademacher, J. A. (1998). The effect of parent participation in strategies to improve the homework performance of students. *Remedial & Special Education, 19*, 131-141.

Carroll, J. B., & Horn, J. L. (1981). On the scientific basis of ability testing. *American Psychologist, 36,* 1012-1020.

Ceci, S. J., Williams, M., & Barnett, S. M. (2009). Women's underrepresentation in science: Sociocultural and biological considerations. *Psychological Bulletin, 135,* 218-261.

Chhin, C. S., Bleeker, M. M., & Jacobs, J. E. (2008). Gender-typed occupational choices: The long-term impact of parents' beliefs and expectations. In H. M. G. Watt, J. S. Eccles (Eds.), *Gender and occupational outcomes: Longitudinal assessments of individual, social, and cultural influences* (pp. 215-234). Washington, DC: American Psychological Association.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences.* Hillsdale, NJ: Erlbaum.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences.* Hillsdale, NJ: Erlbaum.

Conger, A. J. (1974). A revised definition for suppressor variables: A guide to their identification and interpretation. *Educational and Psychological Measurement, 34,* 35-46.

Cooper, H. (1989). *Homework.* White Plains, NY: Longman.

Cooper, H., & Valentine, J. C. (2001). Using research to answer practical questions about homework. *Educational Psychologist*, *36*, 143-153.

Cooper, H., Lindsay, J. J., Nye, B., & Greathouse, S. (1998). Relationships among attitudes about homework, amount of homework assigned and completed, and student achievement. *Journal of Educational Psychology*, *90*, 70-83.

Cooper, H., Robinson, J. C., & Patall, E. A. (2006). Does homework improve academic achievement? A synthesis of research, 1987-2003. *Review of Educational Research, 76*, 1-62.

Costa, P. T. Jr., Terracciano, A., & McCrae, R. R. (2001). Gender differences in personality traits across cultures: Robust and surprising findings. *Journal of Personality and Social Psychology, 81,* 322-331.

Costa, P. T., & McCrae, R. R. (1992). *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) professional manual.* Odessa, FL: Psychological Assessment Resources.

Costa, P. T., McCrae, R. R., & Holland, J. L. (1984). Personality and vocational interests in an adult sample. *Journal of Applied Psychology, 69,* 390-400.

Crombie, G., Sinclair, N., Silverthorn, N., Byrne, B. M., Dubois, D. L., & Trinneer, A. (2005). Predictors of young adolescents' math grades and course enrolment intentions: Gender similarities and differences. *Sex Roles, 52,* 351-367.

Cronbach, L. J., Schönemann, P., & McKie, D. (1965). Alpha coefficients for stratified parallel tests. *Educational and Psychological Measurement, 25*, 291-312.

Dalgety, J., Coll, R. K., & Jones, A. (2003). Development of chemistry attitudes and experiences questionnaire (CAEQ). *Journal of Research in Science Teaching, 40*, 649-668.

De Fruyt, F., & Mervielde, I. (1996). Personality and interest as predictors of educational streaming and achievement. *European Journal of Personality, 10,* 405-425.

De Fruyt, F., & Mervielde, I. (1997). The five-factor model of personality and Holland's riasec interest types. *Personality and Individual Differences, 23,* 87-103.

De Grip, A., & Willems, E. (2003). Youngsters and technology, *Research Policy, 32,* 1771-1781.

De Klerk Wolters, F. (1989). *The attitude of pupils toward technology.* Eindhoven, The Netherlands: Technische Universiteit Eindhoven.

De Klerk, L. F. W., Simons, R. J., & Zuylen, J. G. G. (Eds.) (1989). *Huiswerkbeleid.* Heerlen, The Netherlands: MesoConsult.

De Vries, M. R., & van der Velden, R. K. W. (2005). *Brug of kloof? De ervaringen van HAVO- en VWO-schoolverlaters over de aansluiting tussen VO en HO vóór en ná de invoering tweede fase VO* [Bridge or gap? The experiences of HAVO- and VWO-school-leavers with the junction between secondary and higher education before and after the introduction of the second phase]. Maastricht, The Netherlands: ROA.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227-268.

Dekkers, H. (2002). *Accessible and effective education. New research in a sophisticated theoretical context.* Nijmegen, The Netherlands: KUN.

Dekkers, H. P. J. M., Bosker, R. J., & Driessen, G. W. J. M. (2000). Complex inequalities of educational opportunities. *Educational Research and Evaluation, 6,* 59-82.

Denissen, J. A., Zarrett, N., & Eccles, J. (2007). I like to do it, I'm able, and I know I am: Longitudinal couplings between domain-specific achievement, self-concept, and interest. *Child Development, 78,* 430-447.

Downey, D. B., & Vogt Yuan, A. S. (2005). Sex differences in school performance during high school: Puzzling patterns and possible explanations. *The Sociological Quarterly, 46,* 299-321.

Dryler, H. (1999). The impact of school and classroom characteristics on educational choices by boys and girls: A multilevel analysis. *Acta Sociologica, 42,* 300-319.

Eccles, J. S. (1987). Gender roles and women's achievement-related decisions. *Psychology of Women Quarterly, 11,* 135-172.

Eccles, J. S. (2005). Subjective task value and the Eccles et al. model of achievement-related choices. In A. J. Elliot, & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 105-121). New York: The Guilford Press.

Eccles, J., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1985). Self-perceptions, task perceptions, socializing influences and the decision to enroll in mathematics. In S. F. Chipman, L. R. Brush, & D. M. Wilson (Eds.), *Women and mathematics; Balancing the equation* (pp. 95-121). Hillsdale, NJ: Lawrence Erlbaum Associates.

Education Inspectorate. (2003). *Tweede fase vierde jaar* [Second phase fourth year]. Utrecht, The Netherlands: Education Inspectorate.

Edwards, J. E., & Waters, L. K. (1981). Moderating effect of achievement motivation and locus of control on the relationship between academic ability and academic performance. *Educational and Psychological Measurement, 41*, 585-587.

Edwards, W. (1961). Behavioral decision theory. *Annual Review of Psychology, 12,* 380-417.

Elliot, A. J. (2004). A conceptual history of the achievement goal construct. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 52-72). New York: The Guilford Press.

Elliot, A. J., & McGregor, H. A. (2001). A 2x2 achievement goal framework. *Journal of Personality and Social Psychology, 80,* 501-519.

Elsworth, G. R., Harvey-Beavis, A., Ainley, J., & Fabris, S. (1999). Generic interests and school subject choice. *Educational Research and Evaluation, 5*, 290-318.

England, E. M., & Petro, K. D. (1998). Middle school students' perceptions of peer groups: relative judgments about group characteristics. *Journal of Early Adolescence, 4,* 349-373.

European Commission. (2002). *European benchmarks in education and training: Follow up to the Lisbon European Council.* Brussels, Belgium: European Commission.

European Commission. (2004). *Progress towards the common objectives in education and training. Indicators and benchmarks.* Brussels, Belgium: European Commission.

Evers, A., van Vliet-Mulder, J. C., & Groot, C. J. (2000). *Documentatie van tests en testresearch in Nederland* [Documentation of tests and test research in The Netherlands]. Amsterdam, The Netherlands: NIP/Assen, The Netherlands: Van Gorcum.

Feather, N. T. (Ed.) (1982). *Expectations and actions: Expectancy-value models in psychology.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Feingold, A. (1994). Gender differences in personality: A meta-analysis. *Psychological Bulletin, 116,* 429-456.

Festinger, L. (1957). *A theory of cognitive dissonance*. Evanston, IL: Row, Peterson.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research.* Reading, MA: Addison-Wesley.

Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behaviour. The reasoned action approach.* New York: Psychology Press.

Frost, L. A., Hyde, J. S., & Fennema, E. (1994). Gender, mathematics performance, and mathematics-related attitudes and affect: A meta-analytic synthesis. *International Journal of Educational Research, 21*, 373-385.

Fuller, A. (1991). There's more to science and skills shortages than demography and economics: Attitudes. *Studies in Higher Education, 16,* 333-342.

Furnham, A., & Chamorro-Premuzic, T. (2004). Personality and intelligence as predictors of statistics examination grades. *Personality and Individual Differences, 37,* 943-955.

Gagné, F., & St. Père, F. (2001). When IQ is controlled, does motivation still predict achievement? *Intelligence, 30*, 71-100.

Gardner, P. L. (1975). Attitude to science: A review. *Studies in Science Education, 2,* 1-41.

Gasser, C. E., Larson, L. M., & Borgen, F. H. (2004). Contributions of personality and interests to explaining the educational aspirations of college students. *Journal of Career Assessment, 12,* 347-365.

George, R. (2000). Measuring change in students' attitudes toward science over time: An application of latent variable growth modeling. *Journal of Science Education and Technology, 9,* 213-225.

George, R., & Kaplan, D. (1998). A structural model of parent and teacher influences on science attitudes of eighth graders: Evidence from NELS:88. *Science Education, 82,* 93-109.

Goldberg, L. R. (1993). The structure of phenotypic personality traits. *American Psychologist, 48,* 26-34.

Goldberg, L. R., Sweeney, D., Merenda, P. F., & Hughes, J. E. (1998). Demographic variables and personality: The effects of gender, age, education, and ethnic/racial status on self-descriptions of personality attributes. *Personality and Individual Differences, 24,* 393-403.

Gorard, S., Rees, G., & Salisbury, J. (2001) Investigating the patterns of differential attainment of boys and girls at school. *British Educational Research Journal, 27,* 125-139.

Gottfredson, G. D., Jones, E. M., & Holland, J. L. (1993). Personality and vocational interests: the relation of Holland's six interest dimensions to five robust dimensions of personality. *Journal of Counseling Psychology, 40,* 518-524.

Gottfredson, L. S. (1981). Circumscription and compromise: A developmental theory of occupation aspirations. *Journal of Counseling Psychology, 28,* 545-579.

Green, R. J., & Ashmore, R. D. (1998). Taking and developing pictures in the head: assessing the physical stereotypes of eight gender types. *Journal of Applied Social Psychology, 28,* 1609-1636.

Haladyna, T., Shaughnessy, J., & Shaughnessy, J. M. (1983). A causal analysis of attitude toward mathematics. *Journal for Research in Mathematics Education, 14*, 19-29.

Hamilton, D. L. (Ed.) (1981). *Cognitive processes in stereotyping and intergroup behavior*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Harris, J. A., Vernon, P. A., Johnson, A. M., & Jang, K. L. (2006). Phenotypic and genetic relationships between vocational interests and personality. *Personality and Individual Differences, 40,* 1531-1541.

Hedges, L. V., & Nowell, A. (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science, 269,* 41-45.

Hendriks, A. A. J. (1997). *The construction of the Five-Factor Personality Inventory (FFPI).* Groningen, The Netherlands: Rijksuniversiteit Groningen.

Hendriks, A. A. J., Hofstee, W. K. B., & de Raad, B. (1999a). The Five-Factor Personality Inventory (FFPI). *Personality and Individual Differences, 27,* 307-325.

Hendriks, A. A. J., Hofstee, W. K. B., & de Raad, B. (1999b). *Handleiding bij de Five-Factor Personality Inventory (FFPI)* [The Five-Factor Personality Inventory (FFPI): Professional manual]. Lisse, The Netherlands: Swets Test Publishers.

Hendriks, A. A. J., Kuyper, H., Offringa, G. J., & van der Werf, M. P. C. (2008). Assessing young adolescents' personality with the five-factor personality inventory. *Assessment, 15,* 304-316.

Hendriks, A. A. J., van der Werf, M. P. C., & Kuyper, H. (in preparation). *Personality development in Dutch adolescents.* Manuscript in preparation.

Hermans, H. J. M. (1970). A questionnaire measure of achievement motivation. *Journal of Applied Psychology, 54,* 353-363.

Hermans, H. J. M. (1983). *PMT-K-83. Prestatiemotivatietest voor kinderen* [Achievement motivation test for children]. Lisse, The Netherlands: Swets & Zeitlinger.

Hirschfeld, R. R., Lawson, L., & Mossholder, K. W. (2004). Moderators of the relationship between cognitive ability and performance: General versus context-specific achievement motivation. *Journal of Applied Social Psychology, 34*, 2389-2409.

Hofstee, W. K. B., & Hendriks, A. A. J. (1998). The use of scores anchored at the scale midpoint in reporting individuals' traits. *European Journal of Personality, 12,* 219-228.

Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments* (3rd ed.). Odessa, FL: Psychological Assessment Resources.

Hustinx, P. W. J., Kuyper, H., & van der Werf, M. P. C. (2005). *De onderwijsresultaten van VOCL'89 en VOCL'93 leerlingen verklaard* [The educational results of VOCL'89 and VOCL'93 students explained]. Groningen, The Netherlands: GION.

Janis, I. L., & Mann, L. (1977). *Decision making: A psychological analysis of conflict, choice and commitment.* New York: Free Press.

Jonsson, J. O. (1999). Explaining sex differences in educational choice; An empirical assessment of a rational choice model. *European Sociological Review, 15*, 391-404.

Jörg, A. G. D. (1990). *Oorzaken van de geringe populariteit van het vak natuurkunde als examenvak bij meisjes in het mavo en havo* [Causes of the limited popularity of physics as examination subject with girls in lower and higher general secondary education]. Utrecht, The Netherlands: Centrum voor Didactiek van Wiskunde en Natuurwetenschappen.

Kahneman, D., & Tversky, A. (1972). Subjective probability: A judgment of representativeness. *Cognitive Psychology, 3,* 430-454.

Kahneman, D., & Tversky, A. (Eds.) (2000). *Choices, values and frames.* Cambridge, UK: Cambridge University Press.

Kahneman, D., Slovic, P., & Tversky, A. (Eds.) (1982). *Judgment under uncertainty: Heuristics and biases.* Cambridge, UK: Cambridge University Press.

Kamata, A., Turhan, A., Darandari, E. (2003, April). *Estimating reliability for multidimensional composite scale scores.* Paper presented at the annual meeting of American Educational Research Association, Chicago, IL.

Keeney, R. L., & Raiffa, H. (1993). *Decisions with multiple objectives: Preferences and value tradeoffs.* Cambridge, UK: Cambridge University Press.

Keller, C. (2001). Effect of teachers' stereotyping on students' stereotyping of mathematics as a male domain. *Journal of Social Psychology, 141*, 157-163.

Kendall, L. (1999). Nerd nation: images of nerds in US popular culture. *International Journal of Cultural Studies, 2,* 260-283.

Kinney, D. A. (1993). From nerds to normals: The recovery of identity among adolescents from middle school to high school. *Sociology of Education, 66,* 21-40.

Klimstra, T. A., Hale, W. W., Raaijmakers, Q. A. W., Branje, S. J. T., & Meeus, W. H. J. (2009). Maturation of personality in adolescence. *Journal of Personality and Social Psychology, 96,* 898-912.

Koballa, T. R. (1988). Attitude and related concepts in science education. *Science Education, 72,* 115-126.

Koele, R., & van der Pligt, J. (Eds.) (1993). *Beslissen en beoordelen: Besliskunde in de psychologie* [Decision and assessment: Decision theory in psychology]. Amsterdam, The Netherlands: Boom.

Korf, J., Kamphorst, J., Jongsma, D. M., van der Werf, M. P. C., & Clason, C. E. (1986). *Meisjes en wiskunde; Het HEWET-project. Interimrapport* [Girls and mathematics; Tthe HEWET-project. Interim report]. Groningen, The Netherlands: RION.

Korpershoek, H., Kuyper, H., & van der Werf, M. P. C. (2006). *HAVO-5 en VWO-5 en de tweede fase; De bovenbouwstudie van VOCL'99* [HAVO-5 and VWO-5 and the second phase; The study in the upper grades of VOCL'99]. Groningen, The Netherlands: GION.

Korpershoek, H., Kuyper, H., & van der Werf, M. P. C. (2007). Breed of smal opleiden in het voortgezet onderwijs [Broad or narrow education in secondary education]. In Onderwijsraad [Advisory Council for Education], *Doorstroom in het onderwijs* [Streams in education] (pp. 51-126). Den Haag, The Netherlands: Onderwijsraad.

Korpershoek, H., Kuyper, H., van der Werf, M. P. C., & Bosker, R. J. (2010). Who succeeds in advanced mathematics and science courses? *British Educational Research Journal.*

Kuyper, H., & Otten, W. (1989). Satisfaction and regret about the choice of math. In G. Vergnaud, J. Roglaski, & M. Artique (Eds.), *Proceedings of the annual conference of the International Group for the Psychology of Mathematics Education* (pp. 187-201). Paris, France.

Kuyper, H., & Guldemond, H. (1996). *Vakkenpakketkeuze en toekomstperspectief van VOCL'89 leerlingen in HAVO-5 en VWO-5* [Subject choices and future perspectives of VOCL'89 students in HAVO-5 and VWO-5]. Groningen, The Netherlands: GION.

Kuyper, H., & Swint, F. E. (1996). *Microscopisch schoolloopbaanonderzoek. De eerste drie jaren in het voortgezet onderwijs* [Microscopic research into school careers. The first three years in secondary education]. Groningen, The Netherlands: GION.

Kuyper, H., & van der Werf, M. P. C. (1987). *De invloed van het gedrag van docenten op de prestaties in, keuze van en attituden ten opzichte van wiskunde door meisjes in het AVO/VWO* [The influence of teacher behaviour on girls' achievement in, choice of, and attitudes toward mathematics in secondary education]. Groningen, The Netherlands: RION.

Kuyper, H., & van der Werf, M. P. C. (2003). *VOCL'99-1; De resultaten in het eerste leerjaar* [VOCL'99-1; The results in the first year]. Groningen, The Netherlands: GION.

Kuyper, H., & van der Werf, M. P. C. (2005). *VOCL'99-3; Prestaties en opvattingen van leerlingen in de derde klas van het voortgezet onderwijs* [Performance and view of students in the third grade in secondary education]. Groningen, The Netherlands: GION.

Kuyper, H., Lubbers, M. J., & van der Werf, M. P. C. (2003). *VOCL'99-1: Technisch Rapport.* [VOCL'99-1: Technical Report]. Groningen: GION.

Kuyper, H., van der Werf, M. P. C., & Lubbers, M. J. (2000). Motivation, meta-cognition and self-regulation as predictors of long term educational attainment. *Educational Research and Evaluation, 6,* 181-205.

Laidra, K., Pullmann, H., & Allik, J. (2007). Personality and intelligence as predictors of academic achievement: A cross-sectional study from elementary to secondary school. *Personality and Individual Differences, 42,* 441-451.

Lam, J. W. (1996). The employment activity of Chinese-American high school students and its relationship to academic achievement (Master's thesis, University of Texas at Arlington, 1996). *Masters Abstracts International, 34,* 2148.

Lapan, R. T., Shaughnessy, P., & Boggs, K. (1996). Efficacy expectations and vocational interests as mediators between sex and choice of math/science college majors: A longitudinal study. *Journal of Vocational Behavior, 49,* 277-291.

Larson, L. M., Rottinghaus, P. J., & Borgen, F. H. (2002). Meta-analyses of big six interests and big five personality factors. *Journal of Vocational Behavior, 61,* 217-239.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice and performance. *Journal of Vocational Behavior, 45,* 79-122.

Leslie, L. L., McClure, G. T., & Oaxaca, R. L. (1998). Women and minorities in science and engineering: A life sequence analysis. *Journal of Higher Education, 69,* 239-276.

Li, Q. (1999). Teachers' beliefs and gender differences in mathematics: A review. *Educational Research, 41,* 63-76.

Lightbody, P., & Durndell, A. (1996). Gendered career choice: Is sex-stereotyping the cause or the consequence? *Educational Studies, 22,* 133-146.

Lightbody, P., & Siann, G. (1997). A fulfilling career? Factors which influence women's choice of profession. *Educational Studies, 23,* 25-37.

Lips, H. M. (1992). Gender and science related attitudes as predictors of college students' academic choices. *Journal of Vocational Behavior, 40,* 62-81.

Lounsbury, J. W., Sundstrom, E., Loveland, J. M., & Gibson, L. W. (2003). Intelligence, 'big five' personality traits, and work drive as predictors of course grade. *Personality and Individual Differences, 35,* 1231-1239.

Lubbers, M. (2004). Predicting students' peer acceptance in junior high schools. In M. Lubbers, *The social fabric of the classroom. Peer relations in secondary education* (pp. 57-84). Groningen, The Netherlands: GION.

Lubbers, M. J., van der Werf, M. P. C., Kuyper, H., & Hendriks, A. A. J. (2010). Does homework behavior mediate the relation between personality and academic performance? *Learning and Individual Differences, 20,* 203-208.

Maple, S. A., & Stage, F. K. (1991). Influences on the choice of math/science major by gender and ethnicity. *American Educational Research Journal, 28*, 37-60.

Markus, H., & Nurius, P. (1986). Possible selves. *American Psychologist, 41,* 954-969.

Marsh, H. W. (1990). Causal ordering of academic self-concept and academic achievement: A multiwave, longitudinal panel analysis. *Journal of Educational Psychology, 82,* 646-656.

Martin, A. J., & Dowson, M. (2009). Interpersonal relationships, motivation, engagement, and achievement: yields for theory, current issues, and educational practice. *Review of Educational Research, 79,* 327-265.

Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology, 82,* 60-70.

Midgley, C., Feldlaufer, H., & Eccles, J. S. (1989). Student/teacher relations and attitudes toward mathematics before and after the transition to junior high school. *Child Development, 60,* 981-992.

Ministry of Education, Culture and Science. (2004). *Hoger Onderwijs en Onderzoek Plan 2004* [Higher Education and Research Plan 2004]. Den Haag, The Netherlands: Ministry of Education, Culture and Science.

Mount, M. K., Barrick, M. R., & Strauss, J. P. (1999). The joint relationship of conscientiousness and ability with performance: Test of the interaction hypothesis. *Journal of Management, 25*, 707-721.

Mount, M. K., Barrick, M. R., Scullen, S. M., & Rounds, J. (2005). Higher-order dimensions of the big five personality traits and the big six vocational interest types. *Personnel Psychology, 58,* 447-478.

Mulder, L., Roeleveld, J., & Vierke, H. (2007). Onderbenutting van capaciteiten in basis- en voortgezet onderwijs [Under-utilization of ability in primary and secondary education]. Den Haag, The Netherlands: Onderwijsraad.

Mullis, I. V. S., Martin, M. O., Foy, P. (2008). *TIMSS 2007 International mathematics report. Findings from IEA's trends in international mathematics and science study at the fourth and eighth grades.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I. V. S., Martin, M. O., Robitaille, D. F., & Foy, P. (2009). *TIMSS Advanced 2008 International report. Findings from IEA's trends in international mathematics and science study at the twelfth grade.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Murphy, P. K., & Alexander, P. A. (2000). A motivated exploration of motivation terminology. *Contemporary Educational Psychology, 25,* 3-53.

Muzzatti, B., & Agnoli, F. (2007). Gender and mathematics: Attitudes and stereotype threat susceptibility in Italian Children. *Developmental Psychology, 43,* 747-758.

O'Connor, M. C., & Paunonen, S. V. (2007). Big five personality predictors of post-secondary academic performance. *Personality and Individual Differences, 43,* 971-990.

O'Keefe, D. J. (2002). *Persuasion: Theory & research* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Oliver, J. S., & Simpson, R. D. (1988). Influences of attitude toward science, achievement motivation, and science self concept on achievement in science: a longitudinal study. *Science Education, 72*, 143-155.

Organisation for Economic Co-operation and Development (2007). PISA 2006 Science competencies for tomorrow's world. Paris, France: OECD.

Organisation for Economic Co-operation and Development (2009). *Top of the class – high performers in science in PISA 2006.* Paris, France: OECD.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25,* 1049-1079.

Otten, W., & Kuyper, H. (1988). Gender and mathematics: the prediction of choice and achievement. In A. Borbas (ed.), *Proceedings of the twelfth annual Conference of the International Group for the Psychology of Mathematics Education* (pp. 519-527). Veszprém, Hungary: OOK.

Oyserman, D., Gant, L., & Ager, J. (1995). A socially contextualized model of African American identity: Possible selves and school persistence. *Journal of Personality and Social Psychology, 69,* 1216-1232.

Packard, B. W., & Nguyen, D. (2003). Science career-related possible selves of adolescent girls: A longitudinal study. *Journal of Career Development, 29*, 251-263.

Papanastasiou, C., & Papanastasiou, E. C. (2004). Major influences on attitudes toward science. *Educational Research and Evaluation, 10,* 239-257.

Park, G., Lubinski, D., & Benbow, C. P. (2007). Contrasting intellectual patterns for creativity in arts and sciences: Tracking intellectually precocious youth over 25 years. *Psychological Science, 18,* 948-952.

Parkinson, J., Hendley, D., Tanner, H. (1998). Pupils' attitudes to science in key stage 3 of the national curriculum: A study of pupils in South Wales. *Research in Science & Technological Education, 16*, 165-176.

Pezdek, K., & Berry, T. (2002). Children's mathematics achievement: the role of parents' perceptions and their involvement in homework. *Journal of Educational Psychology, 94*, 771-777.

Pintrich, P. R. (2000). An achievement goal theory perspective on issues in motivation terminology, theory, and research. *Contemporary Educational Psychology, 25,* 92-104.

Pullmann, H., Raudsepp, L., & Allik, J. (2006). Stability and change in adolescents' personality: A longitudinal study. *European Journal of Personality, 20,* 447-459.

Rekers-Mombarg, L. T. M., Korpershoek, H., Kuyper, H, & van der Werf, M. P. C. (2010). *Van studiehuis naar studentenhuis, de studeer-, werk- en persoonlijke situatie van havo- en vwo-eindexamen leerlingen* [From 'studiehuis' to student home, the study, work, and personal issues of 'havo' and 'vwo' graduates]. Groningen, The Netherlands: GION.

Research Centre for Education and the Labour Market. (2005). *Schoolverlaters tussen onderwijs en arbeidsmarkt 2004* [School-leavers between education and labour market 2004]. Maastricht, The Netherlands: ROA.

Research Centre for Education and the Labour Market. (2006). *Schoolverlaters tussen onderwijs en arbeidsmarkt 2005* [School-leavers between education and labour market 2005]. Maastricht, The Netherlands: ROA.

Reynolds, A. J., & Walberg, H. J. (1991). A structural model of science achievement. *Journal of Educational Psychology, 83*, 97-107.

Reynolds, A. J., & Walberg, H. J. (1992). A structural model of high school mathematics outcomes. *Journal of Educational Research, 85*, 150-158.

Reynolds, D., & Teddlie, C. (2000). An introduction to school effectiveness research. In C. Teddlie & D. Reynolds (Eds.), *The international handbook of school effectiveness research* (pp. 3-25). London, UK: Falmer Press.

Roger, A., & Duffield, J. (2000). Factors underlying persistent gendered option choices in school science and technology in Scotland. *Gender and Education, 12,* 367-383.

Rosenbloom, J. L., Ash, R. A., Dupont, B., & Coder, L. (2008). Why are there so few women in information technology? Assessing the role of personality in career choices. *Journal of Economic Psychology, 29*, 543-554.

Sackett, P. R., Gruys, M. L., & Ellingson, J. E. (1998). Ability-personality interactions when predicting job performance. *Journal of Applied Psychology, 83*, 545-556.

Schiefele, U., & Csikszentmihalyi, M. (1995). Motivation and ability as factors in mathematics experience and achievement. *Journal for Research in Mathematics Education, 26*, 163-181.

Schinka, J. A., Dye, D. A., & Curtiss, G. (1997). Correspondence between five-factor and riasec models of personality. *Journal of Personality Assessment, 68,* 355-368.

Schreiber, J. B. (2002). Institutional and student factors and their influence on advanced mathematics achievement. *Journal of Educational Research, 95,* 247-259.

Second Phase Advisory Point. (2005). *Zeven jaar tweede fase, een balans; Evaluatie tweede fase* [Seven years second phase, an audit; Evaluation second phase]. Den Haag, The Netherlands: Tweede Fase Adviespunt.

Sells, L. W. (1980). Mathematics: the invisible filter. *Engineering Education, 70,* 340-341.

Shores, M. L., & Shannon, D. M. (2007). The effects of self-regulation, motivation, anxiety, and attributions on mathematics achievement for fifth and sixth grade students. *School Science and Mathematics, 107*, 225-236.

Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review, 63,* 129-138.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest and academic engagement. *Journal of Educational Research, 95*, 323-332.

Statistics Netherlands. (2008). *Statline.* Voorburg/Heerlen, The Netherlands: CBS.

Statistics Netherlands. (2010). *Statline.* Voorburg/Heerlen, The Netherlands: CBS.

Stead, K. (1985). An exploration, using Ajzen and Fishbein's theory of reasoned action, of students' intention to study or not to study science. *Research in Science Education, 15,* 76-85.

Steinmayr, R., & Spinath, B. (2008). Sex differences in school achievement: What are the roles of personality and achievement motivation? *European Journal of Personality, 22,* 185-209.

Sternberg, R. J. (1999). Intelligence as developing expertise. *Contemporary Educational Psychology, 24,* 359-375.

Stipek, D. J., & Gralinski, J. H. (1991). Gender differences in children's achievement-related beliefs and emotional responses to success and failure in mathematics. *Journal of Educational Psychology, 83,* 361-371.

Stokking, K. M. (1995). *De keuze van natuurkunde als examenvak in het vwo; verschillen tussen jongens en meisjes?* [Choosing physics as examination subject in pre-university education; differences between boys and girls?]. Utrecht, The Netherlands: ISOR/Universiteit Utrecht.

Stokking, K. M. (2000). Predicting the choice of physics in secondary education. *International Journal of Science Education, 22*, 1261-1283.

Sullins, E. S., Hernandez, D., Fuller, C., & Tashiro, J. S. (1995). Predicting who will major in a science discipline. Expectancy-value theory as part of an ecological model for studying academic communities. *Journal of Research in Science and Technology, 32,* 99-119.

Tempelaar, D. T., Gijselaers, W. H., van der Loeff, S. S., & Nijhuis, J. F. H. (2007). A structural equation model analyzing the relationship op student achievement motivations and personality factors in a range of academic subject-matter areas. *Contemporary Educational Psychology, 32,* 105-131.

Tiedemann, J. (2000). Parents' gender stereotypes and teachers' beliefs as predictors of children's concept of their mathematical ability in elementary school. *Journal of Educational Psychology, 92,* 144-151.

Tocci, C. M., & Engelhard Jr., G. (1991). Achievement, parental support, and gender differences in attitudes toward mathematics. *Journal of Educational Research, 84*, 280-286.

Tokar, D. M., & Swanson, J. L. (1995). Evaluation of the correspondence between Holland's vocational personality typology and the five-factor model of personality. *Journal of Vocational Behavior, 46,* 89-108.

Tokar, D. M., Fischer, A. R., & Subich, L. M. (1998). Personality and vocational behavior: A selected review of the literature, 1993-1997. *Journal of Vocational Behavior, 53,* 115-153.

Tokar, D. M., Vaux, A. & Swanson, J. L. (1995). Dimensions relating Holland's vocational personality typology and the five-factor model. *Journal of Career Assessment, 3,* 57-74.

Trautwein, U. (2007). The homework-achievement relation reconsidered: differentiating homework time, homework frequency, and homework effort. *Learning and Instruction, 17*, 372-388.

Trautwein, U., Köller, O., Schmitz, B., & Baumert, J. (2002). Do homework assignments enhance achievement? A multilevel analysis in 7th-grade mathematics. *Contemporary Educational Psychology, 27*, 26-50.

Triantaphyllou, E. (2000). *Multi-criteria decision making methods: A comparative study.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Trusty, J., & Robinson, C. R. (2000). Effects of gender, socioeconomic status, and early academic performance on postsecondary educational choice. *Journal of Counseling & Development, 78*, 463-472.

Uerz, D., Dekkers, H., & Beguin, A. (2004). Mathematics and language skills and the choice of science subjects in secondary education. *Educational Research and Evaluation, 10,* 163-182.

Van Berkel, K. (1999). *Steekproef voor VOCL'99* [Sample for VOCL'99]. Heerlen, The Netherlands: CBS.

Van den Brink, W. P. (1993). Beslissingsmodellen [Decision models]. In R. Koele & J. van der Pligt (Eds.), *Beslissen en beoordelen: Besliskunde in de psychologie* [Decision and assessment: Decision theory in psychology] (pp. 68-95). Amsterdam, The Netherlands: Boom.

Van der Broek, A., Kerstens, J., Hulsen, M., & Sijbers, R. (2004). *Studentenmonitor 2003: Studeren in het hoger onderwijs.* [Student monitor 2003: Studying at higher education]. Den Haag, The Netherlands: Ministerie van Onderwijs, Cultuur en Wetenschappen.

Van Dijk, H., & Tellegen, P. J. (1994). *Handleiding, testboekje, instructieboekje GIVO, Groninger intelligentietest voor voortgezet onderwijs* [Manual, test book, instruction book GIVO, Groninger intelligence test for secondary education]. Lisse, The Netherlands: Swets & Zeitlinger.

Van Heugten, J. (1993). *Vakkenpakketkeuze op het VWO; Attitudes tegenover een B-pakket en een technische studie* [Subject choice in pre-university education; Attitudes towards science-oriented subjects and technical studies]. Eindhoven, The Netherlands: OCTO.

Van Langen, A. (2005). *Unequal participation in mathematics and science education.* Nijmegen, The Netherlands: ITS.

Van Langen, A., & Dekkers, H. (2005). Cross-national differences in participating in tertiary science, technology, engineering and mathematics education. *Comparative Education, 41,* 329-350.

Van Langen, A., & Vierke, H. (2006). *Het onderbenutte bètatalent van VWO-leerlingen* [The not utilized science talent of pre-university students]. Nijmegen, The Netherlands: ITS.

Van Langen, A., & Vierke, H. (2008). *Het onderbenutte bètatalent van Havo-leerlingen* [The not utilized science talent of students in senior general secondary education]. Den Haag, The Netherlands: Platform Bèta Techniek.

Van Langen, A., & Vierke, H. (2009). *Wat bepaalt de keuze voor een natuurprofiel? De invloed van de leerling, de school, de ouders en de peergroup* [What determines choosing a science-oriented study profile? The impact of the student, the school, the parents and the peergroup]. Den Haag, The Netherlands: Platform Beta Techniek.

Van Langen, A., Rekers-Mombarg, L., & Dekkers, H. (2006). Exact kiezen na de invoering van profielen in havo en vwo [Changes in math and science choice following introduction of compulsory study profiles into Dutch secondary education]. *Pedagogische Studiën, 2,* 122-137.

Van Langen, A., Rekers-Mombarg, L., & Dekkers, H. (2008). Mathematics and science choice following introduction of compulsory study profiles into Dutch secondary education. *British Educational Research Journal, 34,* 733-745.

Van Schie, E. C. M. (1993). Heuristieken en probleempresentatie [Heuristics and problem representation]. In R. Koele & J. van der Pligt (Eds.), *Beslissen en beoordelen: Besliskunde in de psychologie* [Decision and assessment: Decision theory in psychology] (pp. 123-155). Amsterdam, The Netherlands: Boom.

Verhorst, J., & Verhulst, C. T. A. M. (1993). *De keuze voor een bèta-studie; Onderzoek naar het keuzeproces van vwo-bèta-leerlingen voor het vervolg op de vwo-opleiding* [Choosing a science-oriented study; Research into pre-university science students' choice processes]. Utrecht, The Netherlands: STOGO.

Wagner, P., Schober, B., & Spiel, C. (2008). Time investment and time management: An analysis of time students spend working at home for school. *Educational Research and Evaluation, 14*, 139-153.

Walter, E., & Bulhosen, P. (Eds.) (2008). *Cambridge advanced learner's dictionary* (3rd ed.). Cambridge, UK: Cambridge University Press.

Warps, J. (2001). *Kiezen voor bèta in het wetenschappelijk onderwijs; Een onderzoek naar de keuze voor zachte- en harde bètaopleidingen door vwo-wo doorstromers* [Choosing science at University; Research into pre-university students' choice of soft and hard science-oriented studies]. Nijmegen, The Netherlands: IOWO.

Watt, H. M. G., & Eccles, J. S. (Eds.). (2008). *Gender and occupational outcomes: Longitudinal assessments of individual, social, and cultural influences.* Washington, DC: American Psychological Association.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32,* 387-398.

Weiner, B. (1986). *An attributional theory of motivation and emotion.* New York: Springer-Verlag.

Weisgram, E. S., & Bigler, R. S. (2007). Effects of learning about gender discrimination on adolescent girls' attitudes toward and interest in science. *Psychology of Women Quarterly, 31*, 262-269.

Wigfield, A., & Eccles, J. S. (Eds.) (2002). *Development of achievement motivation.* San Diego, CA: Academic Press.

Willems, E. J. T. A. (1993). *Jongeren en techniek: Studie- en beroepskeuzes, waardering en beeldvorming ten aanzien van techniek* [Adolescents and technology: Study choice and choice of profession, appreciation and conceptualization of technology]. 's-Gravenhage, The Netherlands: Ministerie van Economische Zaken.

Wolf, M. B., & Ackerman, P. L. (2005). Extraversion and intelligence: A meta-analytic investigation. *Personality and Individual Differences, 39,* 531-542.

Woolnough, B. (1994). Why students' choose physics, or reject it. *Physics Education, 29,* 368-374.

Wright, P. M., Kacmar, K. M., McMahan, G. C., & Deleeuw, K. (1995). P = f(MXA): Cognitive ability as a moderator of the relationship between personality and job performance. *Journal of Management, 21*, 1129-1139.

Zuckerman, D. M., & Sayre, D. H. (1982). Cultural sex-role expectations and children's sex-role concepts. *Sex Roles, 8,* 853-862.